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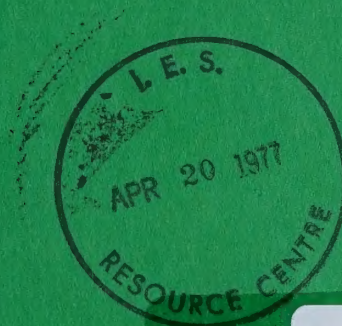
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Drying Potato Wastes for Animal Feed as an Alternative Disposal Method



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Report EPS 3-WP-77-4

Water Pollution Control Directorate
March 1977

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REPORT

DRYING POTATO WASTES FOR ANIMAL FEED
AS AN ALTERNATIVE DISPOSAL METHOD

by

Canadian Bio Resources Consultants Ltd.
Surrey, B.C.

for the

Abatement and Compliance Branch
Environmental Protection Service
Water Pollution Control Directorate
FISHERIES AND ENVIRONMENT CANADA

Report No. EPS 3-WP-77-4
March 1977

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ABSTRACT

The solid wastes produced by the potato processing industry contribute significantly, in some cases, to pollution of the environment. This study was undertaken to evaluate the potential for dehydrating these waste solids for use as an animal feed and, thus, reduce their disposal in environmentally unacceptable ways. This evaluation consisted of determining the marketability of dried potato waste in terms of conventional feedstuffs, assessing drying technology to determine systems applicable to dry potato processing waste, and assessing the potential market for a suitable drying system. The results of the study show that potato wastes can be dried economically and that the dried product can compete in the market as a high energy feed for ruminant animals.

RÉSUMÉ

Les déchets solides provenant du traitement de la pomme de terre contribuent parfois, de façon appréciable, à la pollution de l'environnement. Nous avons donc entrepris d'évaluer la possibilité de les déshydrater pour en faire une provende et, par le fait même, atténuer la pollution qu'ils causent. L'évaluation a porté sur le potentiel commercial des résidus séchés par rapport aux provendes traditionnelles, sur les techniques de séchage pour déterminer celles qui conviennent le mieux et sur le marché potentiel d'un système de séchage convenable. L'expérience a démontré que les résidus de pommes de terres peuvent être séchés économiquement et que le produit déshydraté peut faire concurrence sur le marché comme provende fortement énergétique destinée aux ruminants.

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SUMMARY

In Canada, approximately 1.8 billion pounds of potatoes are processed annually, with a resulting production of approximately 450 million pounds of solid waste. This waste is the by-product of unit processes within the plant and can vary in physical and chemical characteristics from plant to plant. The combined wastes have a high pollution potential and, if disposed of improperly, can have serious environmental consequences. This same solid waste represents a potential source of animal feed. There are, however, difficulties associated with the handling and feeding of this material. In Canada, potato processing waste solids are presently disposed by land fill and as cattle feed.

Feedstuff Evaluation and Marketability

A variety of feedstuffs are used in formulating feeds to meet the requirements of livestock in terms of maintenance and growth. These feedstuffs are used to meet the energy, protein, vitamin and mineral requirements of the livestock and are subject to certain restrictions to ensure optimum performance. Potato waste can be used as a feedstuff for beef cattle, primarily as source of energy. Wet potato waste has been used intensively as a feed for beef cattle in the Pacific Northwest regions of the United States for the past 10-15 years. There are a variety of methods for preparing and feeding of potato wastes, the predominant method being the fermentation of the waste in a pit and the inclusion of the fermented waste as a portion of the feed ration. In the arid regions of central Washington, with its moderate winter climate, this material is used successfully as the major portion of rations for finishing beef cattle. In the colder regions of North America, the feeding of wet potato waste is confined to the warmer months because this high moisture material freezes during cold weather. A further constraint on the feeding of wet potato waste is the overall economics associated with the cattle feeding industry. Some regions are better suited to the feeding of cattle in terms of availability of feeder cattle, market locations and economics, and climatic influence on the capital costs relative to type and cost of buildings. The use of wet potato waste is also limited by the high cost of transporting this material, because of its high moisture content.

As a result of these constraints on the use of wet potato waste, attempts have been made to dry this product. Dried potato waste has value in ruminant rations as an energy source. At present, two manufacturers in North America are marketing dried potato waste as a feed for cattle. The product has received good market response when sold at approximately 75% of the price of barley.

If potato waste is to be included in rations for beef cattle, it must be able to compete with other feed ingredients in the market place. Conventional energy feedstuffs in Canada are primarily produced in the Prairie Provinces and shipped to the grain deficient regions of the country. In the grain deficient Maritimes, potato waste could provide an alternative to western feed grains. In New Brunswick, potato waste could supply over 90% of the energy in rations for cattle on feed. However, these cattle are held only in small numbers and the use of wet potato waste, because of the specialized handling procedures required, is not feasible. Dried potato waste, however, would not suffer from this limitation.

Dryer Evaluation

One type of dryer, the direct-fired rotary, is presently being used to dehydrate potato wastes. At present, there are only two such installations in North America, one in Maine and one in North Dakota. There have been other attempts in Canada and the U.S.A. to dry potato waste but all of these have been abandoned.

In preliminary selection of other drying systems that may have application for drying potato wastes, consideration must be given to the system compatibility of the drying process and material to be dried, the effect the drying process has on the material in terms of feed quality, the air pollution potential of the drying process, the versatility of the dryer with other feedstock materials, and the cost of the dryer system.

One other type of drying system that shows good potential for drying potato wastes is the sonic dryer. An installation in the state of Washington is presently used to dehydrate wet poultry manure.

A subjective comparison between the rotary and sonic dryers indicates that, while the direct-fired rotary system is more complex and perhaps requires closer operating control than the sonic system, there is

operating proof that this system is suitable for drying potato wastes. Further field work is required to substantiate the application of the sonic dryer with potato wastes.

Three other dryer types, the double drum, flash, and TorusDisc may also have potential, but field trials would be necessary to substantiate this preliminary assessment.

Potential Market for a Dryer System

Among the factors that affect the potential market for a potato waste drying system, perhaps the most important are: 1) whether there is need for a particular processing plant or regional group of plants to consider an alternative to their present disposal practices, i.e. present practices may be environmentally unacceptable or economically unattractive; and 2), whether the drying option competes economically with other acceptable disposal alternatives for a particular processor.

Economics for the direct-fired rotary and sonic drying systems show a net return to the processor from the sale of dried potato wastes as livestock feed. However, these economics are general in scope and do not necessarily apply to any particular processing plant.

Based on the constraints on successful use of alternative disposal methods, there appears to be a potential market for a potato waste drying system in British Columbia, Alberta, Manitoba, Quebec, and the Maritime provinces. The biggest potential would appear to be in New Brunswick.

Overview Conclusion

In overview, an assessment of solid waste management for a potato processing plant, or for that matter, any food processing plant with solid waste by-products, can only be made by examining the boundary conditions (climate, regional energy constraints, regional economics, pollution abatement regulations, etc.) that characterize the situation. The various combinations of boundary conditions found throughout North America dictate how a particular option for waste or disposal is to be designed and what option is the most favourable for the given location or set of boundary conditions.

1 INTRODUCTION

1.1 General

The potato processing industry creates a large amount of organic solid waste each processing season. Of the 1.8 billion pounds of potatoes used to produce frozen french fries, potato chips, instant mashed potatoes, canned potatoes, and a variety of snack foods in Canada each year, about 25%, or 450 million pounds, ends up as solid waste.

Two end-of-plant techniques are presently used to dispose of the majority of this waste: use as an animal feed; and, disposal by landfill and land dumping. The value of potatoes as a high energy feed for ruminant animals has long been recognized, but it is only recently that attention has been focused on the use of potato processing wastes as a feed. This interest is primarily due to its value/cost attractiveness when compared to conventional feeds, and because it is an alternative to landfill and land dumping practices which, in many cases, can cause pollution of the environment.

As a feed material, the wet potato waste is usually incorporated into rations without further processing. However, because of its high moisture content, in the range of 82-88%, a number of limitations not normally encountered with conventional feeds are associated with transporting, handling and feeding this material. These limitations, while not insurmountable, have restricted the utilization of potato wastes as an animal feed in some of the major processing regions of Canada.

An alternative to wet feeding is dehydrating the potato waste solids to produce a feed material that is similar in handling and nutritional characteristics to conventional energy feedstuffs. At the outset of this study, it was known that at least one major processor in the United States was drying its wastes for animal feed, but that the industry as a whole was unaware or skeptical of the technical and economic viability of doing so. The purpose of this study, therefore, was to evaluate the role that dehydration of potato wastes might play in Canada as an alternative waste disposal practice, and to prepare a report on the subject which would be useful to processors, engineers and regulatory personnel in waste management decision making.

New federal guidelines respecting liquid effluents from potato processing plants will require many plants presently discharging effluent to waters frequented by fish to upgrade their wastewater treatment systems. It is also becoming common to base municipal sewer surcharge rates for industrial users on the organic loads imposed on the system. These two factors will have the effect of increasing the efficiency of waste solids recovery at the processing plant. It is paramount to the public interest that environmentally acceptable ways of disposing of this waste are implemented. The use of this waste product as an animal feed shows high potential in meeting this goal.

1.2 Objectives

Specific objectives of this study were:

- 1) to evaluate, on a Canada-wide basis, the market potential for an animal feed consisting of dried wastes from the potato processing industry;
- 2) to evaluate dehydration systems for use in drying wastes from the potato processing industry; and,
- 3) to assess the potential market for a drying system for dehydration of potato processing wastes with emphasis on a system of Canadian manufacture.

1.3 Approach

A literature review was carried out in the areas of potato waste utilization as a feedstuff, and dehydration of potato processing wastes (or similar materials). Secondly, first-hand information was assembled from researchers, feedlot operators, Environmental Protection Service personnel, dryer manufacturers, potato processing plant personnel, and dryer operators. This latter work forms the backbone of the study results.

Two EPS in-house reports, "State-of-the-Art Review of Potato Processing Wastewater Treatment and Reuse", by J.P. Stephenson and V.K. Chawla, and "An Inventory of the Potato Processing Industry in Canada", by D.W. Bissett, were used extensively in the preparation of this report. A Canada Agriculture publication, "Guidelines for Feeding Potato Processing Wastes and Culls", by J.W.G. Nicholson, was also a major reference.

Section 2 of this report gives background information regarding solid wastes and the potato processing industry; Section 3 compares potato wastes, both wet and dried, to conventional feedstuffs in terms of nutritional value; criteria for assessing the marketability of potato wastes as an animal feedstuff are developed in Section 4; Section 5 deals with drying systems that are presently used or that may have potential in drying potato wastes; the potential market for a drying system is assessed in Section 6; and, conclusions and recommendations for further work are given in Section 7.

2 BACKGROUND - POTATO PROCESSING RELATIVE TO SOLID WASTES

2.1 Industry Background

Potatoes processed in Canada account for about 37% of the Canadian potato crop, or 1.8 out of 4.8 billion pounds annually [1]; the remaining 63% is used as table potatoes and seed potatoes. The distribution of quantities processed shown in Figure 1 indicates that 25% of Canadian processing is located in western New Brunswick, and about 15% each in Alberta, Manitoba, Ontario, and Quebec. Potatoes are mostly processed to frozen french fries (51%) and potato chips (31%) [2]. Other products include dehydrated potatoes, canned potatoes, starch and potatoes preserved in a foil pouch.

In the U.S.A., about seven times as many potatoes are grown (34 billion pounds), and about eight times as many are processed (14.4 billion pounds), as in Canada. Processing is concentrated in the large potato growing areas of the north: Washington, Oregon, Idaho, North Dakota, Minnesota, and Maine. Almost 40% of potato processing is carried out in Idaho and adjacent Malheur Co., Oregon. Products include frozen french fries (42%), potato chips (24%), and dehydrated products (22%) [3].

2.2 Potato Processing Plant

A processing plant is composed of a series of unit processes, beginning with transport and storage input to the plant, followed by a sequence of steps as throughput through the plant, and ending with transport and storage of finished product, and waste treatment and discharge of waste as output from the plant. The configuration of unit processes and the components of individual unit processes differ with the end products desired. Waste is generated at individual unit processes and can be collected and discharged from the plant as a liquid portion and solids portion.

In order to assess the animal feed potential of potato wastes and assess dehydration technology applicable to this material, characterization of the waste, with an indication of industry-wide variation, is necessary. This is best done by examining the wastes produced at each unit process.

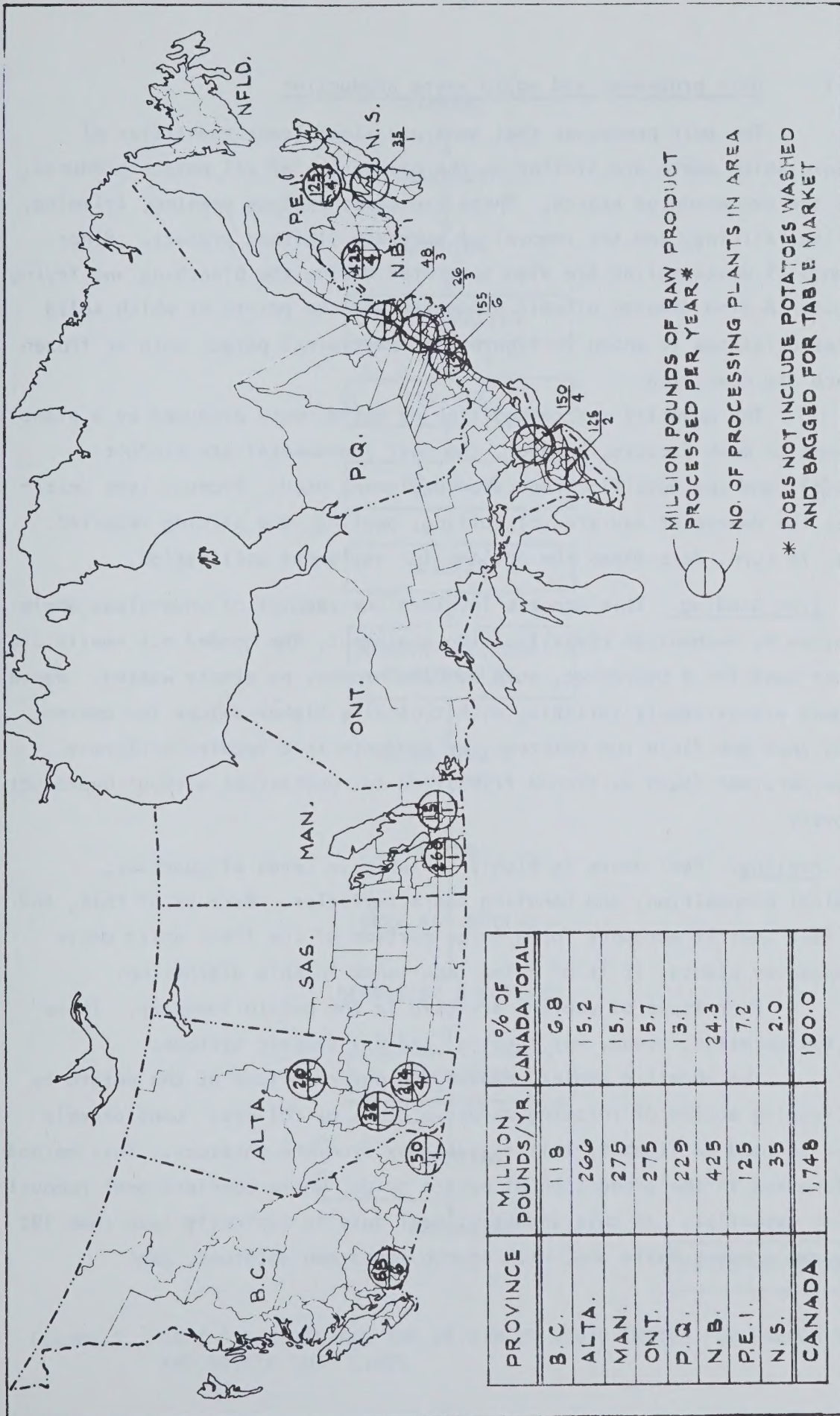


FIGURE 1. DISTRIBUTION OF QUANTITY OF POTATOES PROCESSED AND PROCESSING PLANTS IN CANADA

2.2.1 Unit processes and solid waste production

The unit processes that generate significant quantities of organic solid waste are similar in the production of all potato products, with the exception of starch. These processes include peeling, trimming, culling, slicing, and the removal of subgrade finished product. Minor amounts of waste solids are also generated during the blanching and frying stages. A flow diagram of unit processes and the points at which solid wastes originate is shown in Figure 2 for a typical potato chip or frozen french fry operation.

The quantity and composition of solid waste produced by a plant depends on many factors; however, the most fundamental are product type(s), and the specific production equipment used. Product type determines the degree of raw product culling, peeling, and slicing required. This, in turn, determines the options for equipment utilization.

(a) Size Grading. This process involves the removal of undersized whole potatoes by mechanical classification equipment. The graded out smalls are either used for a byproduct, such as hash browns, or simply wasted. Waste volumes are extremely variable, with typically higher values for operations that use field run potatoes for products that require uniformly sized potatoes (such as french fries) and for operations without byproduct recovery.

(b) Peeling. Peel waste is highly variable in terms of quantity, chemical composition, and handling characteristics. Because of this, and the fact that it accounts for a large portion of the total solid waste produced by plants, it is of prime importance in this discussion.

Four types of peelers are used in the potato industry. These are the abrasive, steam, wet caustic, and dry caustic systems.

The abrasive peeler removes the outer surface of the potato by the rasping action of rotating abrasive discs or rollers. Considerable water is used in flushing this tissue away from the potatoes. This method is favoured in the production of potato chips, where complete peel removal is not essential. In this industry, peel loss is typically less than 10% on a raw product basis and, with smooth round new potatoes, can

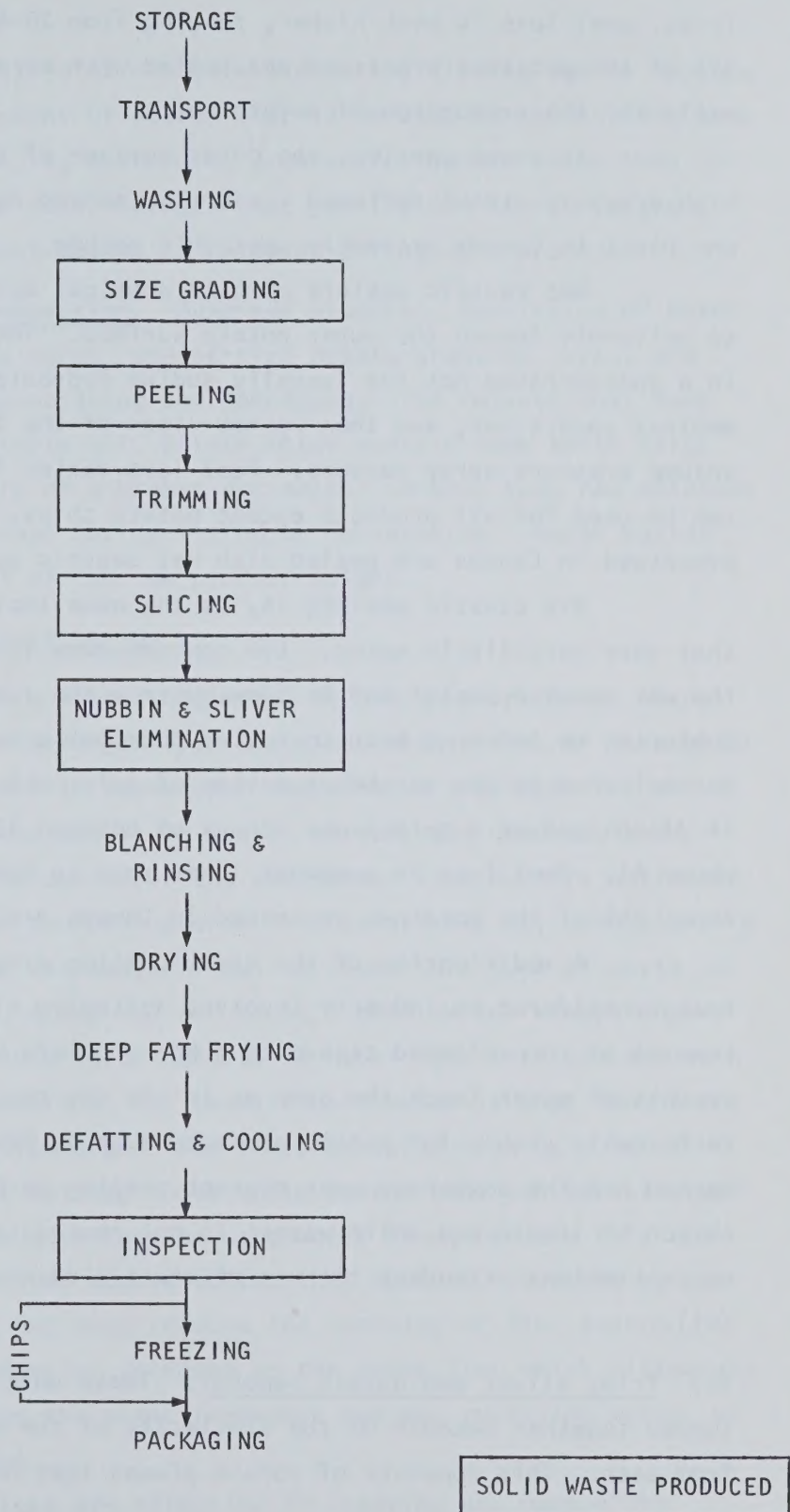


FIGURE 2. UNIT PROCESSES AND THE ORIGIN OF SOLID WASTES FOR FRENCH FRY AND POTATO CHIP LINES

be less than 5%. For products requiring full peel removal, as with french fries, peel loss is much higher, ranging from 20-40%. In Canada, about 32% of the potatoes processed are peeled with abrasive peelers, principally for the production of potato chips.

In steam peeling, the outer surface of the potato is cooked by high pressure steam¹ softened tissue is removed by vigorous washing. Only one plant in Canada presently uses this method.

Wet caustic peelers combine chemical attack and heat treatment to uniformly loosen the outer potato surface. The potatoes are immersed in a concentrated hot lye (usually sodium hydroxide) solution, held at ambient conditions, and then washed clean of the loosened material by high volume pressure spray washers. Peel loss varies from 15-30%. This method can be used for all products except potato chips. About 42% of potatoes processed in Canada are peeled with wet caustic peelers.

Dry caustic peeling is, as the name implies, a caustic process that uses very little water. Lye contact time is generally longer than in the wet caustic peeler and in some systems the lye covered potatoes are subjected to infrared heat to hasten chemical attack. Peel removal is accomplished by the scrubbing action of soft rubber rollers. Peel waste is discharged as a gelatinous slurry of between 15-20% solids and a pH above 11. Peel loss is somewhat lower than in the wet caustic system. About 24% of the potatoes processed in Canada are peeled in this manner.

A modification of the steam peeling process which is presently being considered by industry involves softening of the peel by steam and removal of the softened tissue by rubber rollers without the use of large amounts of water (much the same as in the dry caustic process). If technically viable for potato products such as french fries, this peeling method has the advantage over present peeling methods in that land application of liquid and solid wastes is not restricted by the high sodium concentrations attendant the use of caustic chemicals [see Section 2.2.3 (d)].

(c) Trim, sliver and nubbin removal. These unit processes have been lumped together because of the similarity of the solid waste generated from each. This consists of potato pieces that have been removed from

processing, either mechanically or by hand, because of blemishes, rot, and subgrade size and shape.

(d) Slicing. Starch particles are released during slicing due to rupture of potato cells. The amount of starch lost is related to the surface area of the potato slices and is, therefore, greater for potato chips than for french fries. Available data indicate that particulate starch in the order of $\frac{1}{2}$ -3% (raw product basis) is released during this process.

(e) Finished product inspection. Subgrade products, consisting of burnt and off-colour fries and chips, coarse-size potato granules, etc., are removed prior to final processing and packaging. The rejects that have been fried contain vegetable oil; potato chips contain some table salt; and all product types are of a higher dry matter content than raw potatoes because of moisture release during frying or dehydration. Waste solids generated amount to $\frac{1}{2}$ -5% of the raw product weight.

2.2.2 Recovery of waste solids

Solid wastes are either collected at the unit processes where they are generated and discharged from the plant separately, or they enter a common wastewater flow with subsequent end-of-pipe treatment for recovery. Undersized potatoes, trim waste, slivers and nubbins, and subgrade final product seldom enter the wastewater flow but are collected and transported from the processing area in a relatively dry condition. A few plants, however, use wastewater flows to flume this type of waste out of the plant. Abrasive, steam and wet caustic peel wastes always enter the wastewater flow because large amounts of water come into contact with the solids in these operations; dry caustic peel waste is kept out of the wastewater flow and is discharged from the processing area as a thick slurry. It is important to keep those solid wastes that can be collected in a semi-dry state from entering the wastewater flow, because this not only reduces the quantity of coarse solids that must be recovered by the waste treatment system, but also reduces the quantity of fine starch particles and soluble organics released to the waste flow which ultimately impose an organic load on the plant treatment system, receiving water, or municipal treatment works.

Screening devices are effective in removing and dewatering coarse solids from wastewater flows. They are widely used in the Canadian

potato processing industry and recovery of slivers, trim waste, and other coarse potato solids is high.

Recovery of fine starch particles released to the wastewater flow during peeling and slicing is presently carried out primarily by processors that discharge to water courses; those that discharge to municipal sewers have generally made little effort to recover these fine solids. Recovery is accomplished by clarifiers and hydrocyclones with efficiencies generally greater than 70% of the suspended material in the waste flow. In the case of clarifiers, the solids which settle out require additional dewatering, which is commonly accomplished by vacuum filtration. The resulting filter "cake" contains 12-15% solids. Wastewater from about one-third of the production in Canada is treated to recover this portion of the solid waste.

2.2.3 End-of-plant management options

One or a combination of the following techniques is presently used by potato processing plants for ultimate disposal of their solid wastes.

(a) Landfill. Total plant solid wastes or a portion thereof (e.g., caustic peel waste only) are trucked to a municipal or private landfill site where they are buried. This is common for Canadian operations; 65% of the processing plants practice landfilling of their solid wastes to some extent. This practice may or may not represent a pollution problem, depending on selection and management of the landfill site.

(b) Disposal by open pit dumping. Wastes are dumped into a natural depression or excavated pit without plans for subsequent removal or use. At least two Canadian plants are doing this. Serious pollution of surface waters and groundwaters can result from this practice.

(c) Animal feed. Potato wastes are conditioned for feeding to animals in a variety of ways. Perhaps the most common in Canada is mixing all of the wet wastes and storing them in an open pit prior to feeding. The material is often dumped into one end of the pit and removed from the other. This affords some mixing and allows time for the fermentation process to neutralize the alkali (high pH) of material containing caustic peel waste.

This anaerobic process produces organic acids and effectively preserves the material if a pH value less than 4 is obtained. Additional mixing of the material can result in oxidation of these organic acids to carbon dioxide and water, with a net loss in dry matter content. The slurry at the time of feeding will usually contain between 12-18% dry matter, depending on the extent of the above oxidation, evaporation, rainfall, and the original dry matter content of the wastes.

Wastes can also be segregated into a drier portion (product rejects, whole culls, etc.), and a wetter portion (peel waste, filter cake, etc.) before being incorporated into feed rations.

Alternatively, wastes can be dried for animal feed. Presently, no Canadian potato processors dehydrate their waste solids.

Feeding potato waste in some manner is popular in Canada; 65% of the processing plants use some or all of their solid wastes as animal feed.

This topic is fully developed in the next two chapters.

(d) Land disposal as fertilizer and soil conditioner. This method is limited because of the adverse effect on soil and crops of the high sodium content in material containing caustic peel waste, and because of the possible spread of potato disease.

The use of potassium hydroxide (KOH) instead of sodium hydroxide (NaOH) as the caustic chemical used in peeling is being investigated by at least one Canadian plant. This would allow the land spreading option to be carried out with benefit to crops and soil.

3 POTATO WASTE AS A FEEDSTUFF FOR LIVESTOCK

3.1 Basic Feed Formulation

In order to evaluate the use of potato waste as a feedstuff, it is first necessary to describe the different nutrients required by animals and the present methods of supplying these nutrients.

3.1.1 Function of nutrients in livestock feeds

In formulating rations for livestock, a variety of nutrients are required to meet the demands for maintenance and production. These nutrients are:

(a) Carbohydrates. These are found primarily in sugars, starch and cellulose, and are the major source of energy for the animal.

Sugars and starch are relatively easily digested by both non-ruminants (pigs and chickens) and ruminants (cattle). However, cellulose, which makes up most of the crude fibre of the ration, has very limited digestibility in non-ruminants. The rumen of cattle and sheep enables a considerable amount of this fibre to be broken down by micro-organisms so that it can be absorbed by the animal.

Standard sources of energy are feed grains such as corn, wheat, barley, and oats.

(b) Fats. These are an extremely rich source of energy. Digested fat has over twice the energy value of digested carbohydrates. However, the amount of fat that can be included in a ration is limited, since high levels, over 10% of the ration by weight, cannot be tolerated by the digestive systems of certain classes of livestock. The use of fat in a ration is determined by economic comparison with other energy sources.

(c) Proteins. These are essential in the make up of many parts of the animal body, such as muscle, blood, skin bone, hair, enzymes and hormones.

Proteins consist of groups of amino acids which are absorbed in the digestive system and then rebuilt into proteins in the animal body.

There is a distinction between ruminants and non-ruminants in regards to protein digestibility and value. Non-ruminants require specific levels of the various amino acids for optimum performance. These must be included in the ration, since this class of animal does not have the

capability of amino acid synthesis. To meet this amino acid requirement, adequate levels of high quality protein (e.g., soyabean oil meal, fishmeal or meatmeal) must be used in ration formulation or, alternatively, synthetic amino acids must be added to supplement inadequate levels of protein.

Ruminants, however, are capable of synthesizing amino acids and it is, therefore, only necessary to supply an adequate level of digestible protein in the ration. Sources of this protein include the feed grains which are used as energy sources, high quality proteins, or non-protein nitrogen sources such as urea.

(d) Minerals. Many minerals are essential to animal growth and maintenance. Some are already found in adequate quantities in natural feeds, and do not have to be supplemented. The primary minerals that are considered in feed formulation are sodium chloride, calcium, phosphorous, cobalt, and iodine.

(e) Vitamins. Vitamins are required in livestock feeds to perform specific essential functions in animal metabolism. Vitamins that are considered in feed formulation include the fat soluble vitamins (A, D, E and K), and the water soluble vitamins (C and B complex).

3.1.2 Classification of livestock feed constituents

The constituents of livestock feeds are classified into four broad areas.

(a) Concentrates. These are high in energy, low in fibre, and may supply part or all of the protein requirements. The main ingredients classified as concentrates are feed grains and protein meals.

(b) Roughages. These are low in energy, high in fibre, and their quality is measured by their protein, energy and fibre content. The main ingredients classified as roughages are hay, straw and silage. Due to their high fibre content they are mostly fed to ruminants.

(c) Minerals. These are described in Section 3.1.1 (d).

(d) Vitamins. These are described in Section 3.1.1 (e).

3.1.3 Restrictions on feed formulation

There are a number of restrictions on feed formulation, depending on the class of animal, age and productive role. Of particular interest to this study are:

- (a) pH. Feedstuffs with pH values higher than 9 are not recommended.
- (b) Salt. High levels of salt or sodium are not desired and can result in salt poisoning to some classes of livestock.
- (c) Dry matter. In cattle feeding, the dry matter content of the ration should not be less than 25% by weight to obtain optimum performance.
- (d) Roughage. In cattle feeding, a source of roughage is required to maintain normal rumen activity. Rations containing as little as 2 lb (0.9 kg) per day of roughage have been fed successfully to cattle [4].
- (e) Particle size. In cattle feeding, fine feed particle size (powdery) is cited [5] by many researchers as the main cause of bloat.

3.1.4 Role of dried feedstuffs in feed formulation

There are a variety of dehydrated feed ingredients that play an important role in animal nutrition. Examples of these include:

- (a) Alfalfa meal. This product is produced by drying alfalfa. It is widely used in the feed industry for protein value, as a source of essential vitamins, for its effect on egg yolk colour, and as a source of unidentified growth factors.
- (b) Fish meal. This is a byproduct of the fish processing industry and is widely used in non-ruminant rations as a source of high quality protein.
- (c) Brewers and distillers grains. These are, respectively, byproducts of the brewing and distilling industries. They are sources of high quality protein and essential vitamins.
- (d) Beet pulp. This is a byproduct of the sugar beet processing industry and is widely used in cattle rations as an energy and protein source.
- (e) Poultry waste. This is the dried litter from poultry production operations and is a good source of protein and minerals for ruminants. It

is presently available for use in some areas of the United States, but it cannot be included in registered feed rations in Canada.

3.2 The Role of Potato Waste in Animal Nutrition

Byproducts from potato processing have been widely used in North America in recent years as a source of energy in cattle feed. Non-ruminant animals do not use these waste products well unless they have been precooked and, therefore, most potato waste will be fed to cattle unless more economical methods of "pre-cooking" are developed.

For simplification, therefore, all further discussion will apply to cattle nutrition only.

The nutritional value of potato waste varies greatly with the method of production and the product and byproducts being manufactured. The dry matter, crude protein and relative digestibility coefficients of various potato feeds for ruminant animals are shown in Table 1.

3.2.1 Wet potato waste for beef cattle feeding

The use of wet potato waste as a feedstuff for beef cattle is a common practice in many of the potato growing and processing areas of North America. The feeding value, constraints, and the handling of wet potato waste for cattle are well documented by Nicholson [4]. A number of beef cattle feedlots where wet potato wastes were being fed were visited during this study. The type of cattle feeding system and the feeding program varied from location to location. The feedlots observed included open, partially covered, and fully covered slotted floor systems, with the climate being the apparent determining factor on the type of system used.

The feeding programs observed also included a full range of activities, as follows:

- (a) Spreading the material on the ground over the winter and then allowing the cattle to eat it in the spring was observed in the North Dakota-Minnesota area, where the low winter temperatures kept the material frozen until spring.
- (b) The ensiling (fermentation) of potato wastes with chaff (grain harvesting wastes) and self feeding (ad lib) of this material to beef

TABLE 1. DRY MATTER (DM) AND CRUDE PROTEIN (CP) CONTENTS OF VARIOUS POTATO FEEDS, AND THEIR DIGESTIBILITY COEFFICIENTS FOR RUMINANT ANIMALS [41]

	DM %	Digestibility of DM, %	CP % of DM	Digestibility of CP, %
Fresh potato	20.8	82	9.5	62
Screenings from a french fry plant	18	82	8.0	49
Dried potato pulp from a potato starch plant	93	75	7.0	20
Scalper waste from production of potato granules	75	95	9.5	59
Classified waste from production of potato granules	91	92	9.5	65
French fry rejects	47	-	6.2	-
Slurry from a storage pit	13	74	9.0	-
Dehydrated potato waste (mixed screenings and filter cake)	92	86	6.5	0
Instant mashed	21	-	6.5	-
Filter cake	14	-	5.1	-

- not determined

cattle or replacement dairy cattle was observed in Minnesota and reported in the literature by the University of Minnesota [6].

(c) Combination of potato wastes and storage in a pit for subsequent inclusion in a ration for finishing beef cattle was observed at the McGregor Feedlot at Pasco, Washington. This lot had a capacity of 30,000 head and used potato waste for approximately 60% by weight of the ration for finishing beef cattle. Wet potato waste did not constitute a major portion of the ration when cattle were first being put on feed, when calves or smaller animals (less than 700 lb) were being fed, and during periods of cold weather when freezing of the high moisture feed ration in the feed bunks could occur. Because of the relatively moderate climate of the Pasco area, the wet potato wastes in the ration were reduced only for short periods during the winter, to a level of approximately 20%. A similar situation was observed at a commercial feedlot near Boise, Idaho; but here the relatively colder winter resulted in a longer period during which the use of wet potato waste was restricted.

The personnel interviewed at the McGregor Feedlot were well satisfied with the use of potato wastes as a feed-stuff for beef cattle.

(d) Also observed was the separation of the drier portions of the potato waste (cull french fries, cull potatoes, etc.) from the wetter portions (peel waste, screenings, filter cake, etc.). The drier portions were stored in covered bins and the wetter portions combined and stored in a pit to allow fermentation to take place.

The J.R. Simplot Company, a major potato processor, operates three feedlots in Idaho, U.S.A. using this method. These three feedlots have a combined capacity of approximately 90,000 to 100,000 head and finish approximately 250,000 beef cattle per year. These large, well-managed feedlots use potato waste for 50-60% by weight of the total ration during a 120 to 160 day feeding period. Problems they have experienced with the feeding of wet potato waste include: 1) mortality that at times has been higher than desired; and 2) high dry matter losses from the potato waste storage pit. The mortality has been attributed to a virulent strain of microorganisms in the pit, while the dry matter losses would seem to be the result of oxidation of the products of fermentation because of the high level of mixing and recycling of the pit contents. For these

and other reasons, including the increased cost of transporting the wet potato waste from the processing plants to the feedlot, research has begun on the feasibility of drying potato wastes.

In addition to their feedlots in Idaho, the J.R. Simplot Company operated a 2,500 head feedlot at Carberry, Manitoba, which used the potato waste from a nearby potato processing plant. Wet potato waste was only fed during the warmer months, and was dumped and allowed to freeze in pits during the colder months. During the warmer period of the year this product thawed and was then fed. Feedlot personnel were well satisfied with the performance of wet potato wastes in their feeding operations.

As well as the wastes being used by large commercial feeding operations, the separated drier portion was commonly fed to beef and dairy livestock held in small lot numbers on farms close to the processing plant.

(e) A further modification to this separation process was observed at Roslyn Park Farm Limited, located at Petersburg, Ontario, where the peel waste component of the potato waste was kept separate from the balance of the wetter portion. Both portions were allowed limited fermentation, which was activated by the addition of previously stabilized wastes. The degree of fermentation was controlled by the addition of formaldehyde, which stopped the fermentation process at the level desired. This process prevents dry matter losses which can occur during extended fermentation. At this 6,000 head, totally covered slotted floor feedlot, wet potato waste comprised up to 70% of the ration by weight. Rations were carefully formulated using continual laboratory analysis and resulted in average rates of gain of 2.8 lb/day in winter and 3.1 lb/day in summer.

When wet potato waste is fed to beef cattle the amount used in the ration will vary, depending upon the availability and the climate, since the potato waste is subject to freezing during cold weather. A ration, typical of those observed during the study, would be as follows:

Wet Potato Waste	50% by weight
Grain	40% by weight
Roughage	7% by weight
Supplement	3% by weight.

3.2.2 Dried potato waste for beef cattle feeding

Only limited research on the nutritional value of dried potato waste was found. However, since this product is now being produced commercially by such companies as Pillsbury and Tater Meal Co. in the United States, research in this area has been increasing. Current information has mainly been applied to cattle feeding. The following is a summary of the information collected.

(a) Composition. The nutritional content of dried potato waste varies with the type of product being manufactured, the method of production and the length and type of storage. Information obtained through visits to plants producing dried potato wastes indicated that the composition of this product would be as follows:

Crude Protein	6 - 8%
Fibre	2 - 5%
Fat	2.5 - 5%
Ash	13 - 14%
Total Digestible Nutrients	74%
Nitrogen Free Extract	74.5%

Dry matter is usually about 90% of the total; 85% of the dry matter is digestible.

(b) Feed trials. The University of Minnesota has conducted trials comparing dried potato waste with barley as a feed source for cattle [7].

The two rations were as follows:

	<u>I</u> <u>1b/day</u>	<u>II</u> <u>1b/day</u>
Dried potato waste	8.0	-
Ground barley	-	8.0
Urea	0.3	0.1
Corn silage	Free Access	Free Access
Mineral/vitamin	Free Access	Free Access

The animals on dried potato waste received 0.3 lb of urea per day, as compared to 0.1 lb per day for those on the barley ration.

Average daily gain over the 157 day test period slightly favoured the potato fed animals (2.34 lb per day compared to 2.27 lb).

There was no problem with digestive upsets or palatability during the trial period, and the test demonstrated that dried potato waste is nutritionally competitive with barley.

3.3 Summary

A variety of feedstuffs are used in formulating feeds to meet the requirements of livestock in terms of maintenance and growth. These feedstuffs are used to meet the energy, protein, vitamin and mineral requirements of the livestock fed and are subject to certain restrictions to ensure optimum performance. Included in these feedstuffs are a number of dried products that are produced directly or as byproducts of various food processing or related industries. Potato waste can be used as a feedstuff for beef cattle, primarily as a source of energy. A variety of methods for the feeding of potato wastes to cattle were observed, with the predominant method being the fermentation of the waste in a pit and the inclusion of the fermented waste as a portion of the ration. In most instances, potato waste comprised between 50% and 60% of the ration, with lower levels being fed to cattle at the start of the feeding period and during periods of freezing weather. Dried potato waste is being manufactured by two potato plants in the United States and has been shown to be a good feedstuff for beef cattle.

4 MARKETABILITY OF POTATO WASTE AS A FEEDSTUFF

In the previous section potato waste was shown to be a useful feedstuff for beef cattle. However, for potato wastes to be included in beef cattle rations they must replace conventional feedstuffs. The marketability of potato wastes will determine to what extent they will make this replacement.

4.1 Definition of Feed Ingredient Marketability

Basically, there are three stages in the chain of feed ingredient movement and marketing:

- (a) the production of the ingredient;
- (b) the processing of that ingredient; and
- (c) the feeding of that ingredient to livestock.

The decision to proceed with each stage of this marketing chain will be governed by the capability of that ingredient to compete economically with products of a similar nature.

This economic capability will, in turn, be controlled by:

- (a) product cost;
- (b) ease of handling;
- (c) continuity of supply;
- (d) ease of distribution;
- (e) consistency of product quality;
- (f) limitation of use; and,
- (g) product life.

4.2 Supply of Conventional Feedstuffs

The production of livestock and poultry in North America is dependent upon a supply of high energy feedstuffs, protein, vitamins and minerals. The present sources of high energy feedstuffs in Canada are the feed grains produced in the Prairie Provinces, corn produced in Ontario and Quebec, and the importation of U.S. feed grains (mainly corn). The distribution of domestic feed grain production and movement is depicted in Figure 3. This figure shows that the movement of feed grains under the Federal Feed Freight Assistance program is predominantly from the feed grain production areas of the Prairies to the grain deficient areas of Eastern Canada. In 1974-75, assistance under this program amounted to

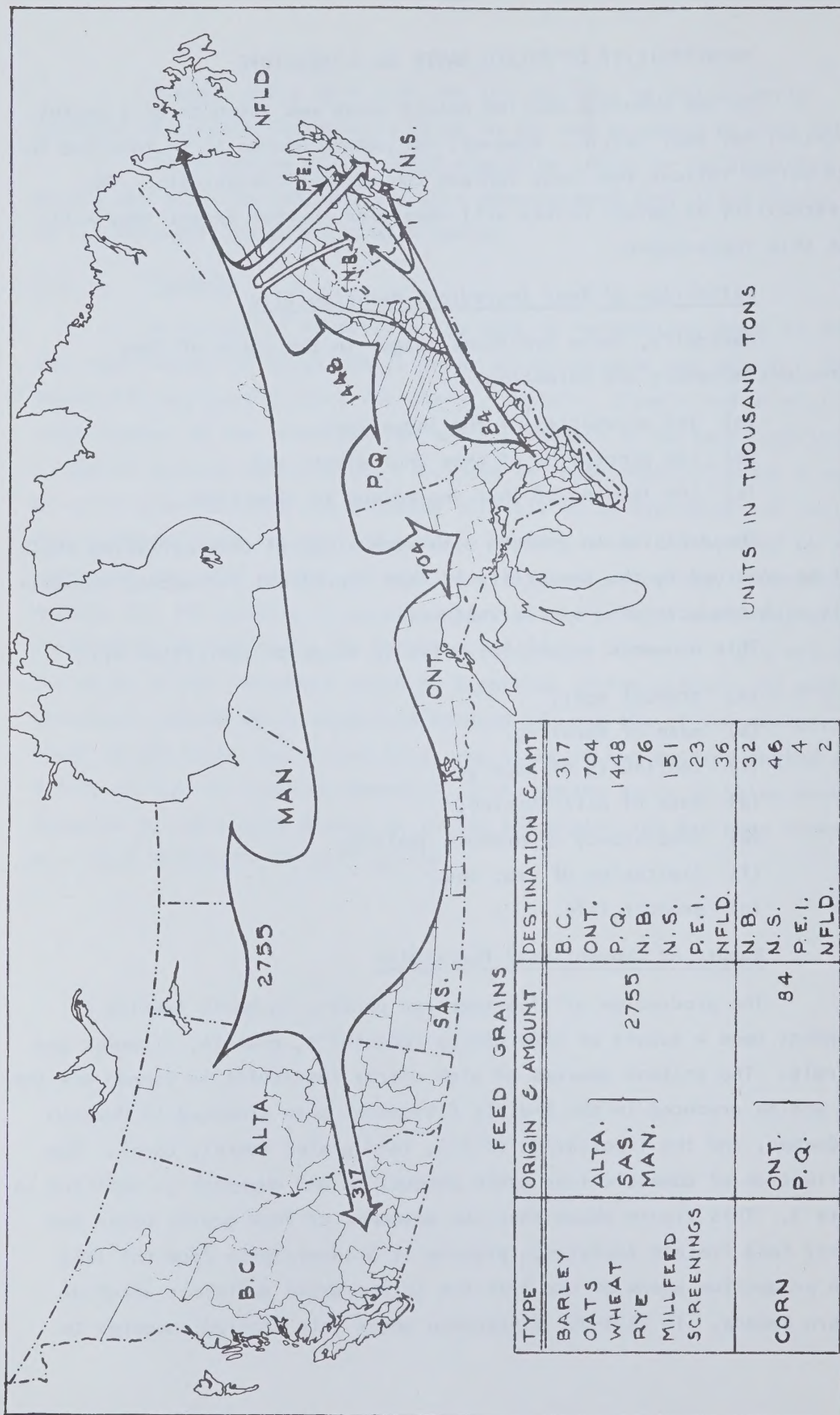


FIGURE 3. DOMESTIC MOVEMENT OF FEED GRAINS (1974/75)

slightly over 21 million dollars [8]. The use of alternative feed-stuffs such as potato waste, could reduce this figure and assist these areas to become less dependent on transported high energy feedstuffs. This is particularly true in the case of cattle feed, since potato waste can be efficiently used by ruminants.

A further reason for developing programs to efficiently use alternative feed sources, such as potato waste, is the ever increasing demand for feed grains in the world market. This demand has resulted in sharply increased prices for feed grains. The long term outlook for feed grain prices must be considered "bullish" as the world moves from a position of relative abundance to relative scarcity. To meet this situation, it becomes apparent that all resources must be used effectively and efficiently. The use of potato wastes to replace feed grains is a prime example of this practice.

The potential impact that potato waste could have on the feed market is shown in the following two tables. Table 2 provides information on the production of potato wastes in Canada, by province. It should be noted that the potato waste figures do not include tonnages of culls from fresh marketing operations. The information in Table 3 relates the production of potato waste to cattle on feed (feedlot cattle). One interesting observation is that potato waste could supply the energy portion of the ration for virtually all of the cattle on feed in New Brunswick. An overview of the statistical data for these cattle indicates that the cattle are located on a large number of farms, with a relatively small number of cattle per farm. The specialized handling procedures required for wet potato waste [see Section 4.3.1 (b)] preclude its use for small lot sizes of cattle. The drying of the potato waste would offer the opportunity for use of this product in these situations.

4.3 Marketing Wet Potato Waste as a Feedstuff

4.3.1 Marketing systems

There are three main systems of marketing wet potato waste in North America. These are:

(a) Used at a processor-owned feedlot. The largest processor-owned feeding operation in North America is the J.R. Simplot Company operation, described previously in Section 3.2.1 (d).

TABLE 2. DISTRIBUTION OF POTATO PROCESSING PLANTS AND ESTIMATED QUANTITIES OF POTATO WASTE

Province	Total No. of Plants ^a	Potatoes Processed millions ^a of lb	% of Canada Total	Estimated Waste ^b (wet) millions of lb	Estimated Waste ^c (dry matter) millions of lb
B.C.	7	118	6.8	29.5	4.4
Alta.	6	266	15.2	66.5	10.0
Sask.	-	-	-	-	-
Man.	2	275	15.7	68.8	10.3
Ont.	6	275	15.7	68.8	10.3
P.Q.	12	229	13.1	57.3	8.6
N.B.	4	425	24.3	106.3	15.9
N.S.	1	35	2.0	8.8	1.3
P.E.I.	4	125	7.2	31.3	4.7
nfld.	-	-	-	-	-
CANADA	42	1748	100.0	437.3	65.5

^aExtracted from EPS questionnaires used in preparation of report "An Inventory of the Potato Processing Industry" [2].

^bCalculated as 25% of total potatoes processed.

^cCalculated as 15% of total wet waste.

TABLE 3. DISTRIBUTION OF CATTLE, CATTLE ON FEED, AND ESTIMATED CAPABILITY OF POTATO WASTES AS A FEED SOURCE

Province	Total Beef Cattle ^a 1000's head	Cattle on Feed ^a 1000's head	Available Potato Waste (dry matter ^b) Million lb	Potential to Finish Cattle ^c 1000's head	% of Cattle on feed
B.C.	470	45	4.4	2.2	4.8
Alta.	3,478	743	10.0	5.0	0.8
Sask.	2,512	371	-	-	-
Man.	1,001	174	10.3	5.1	3.0
Ont.	2,096	699	10.3	5.1	0.7
P.Q.	681	55	8.6	4.3	16.8
N.B.	67	9	15.9	8.0	92.4
N.S.	79	11	1.3	0.6	5.7
P.E.I.	71	17	4.7	2.3	13.5
Nfld.	4	1	-	-	-
CANADA	10,459	2,125	65.5	32.6	1.5

^a1971 Figures, Statistics Canada^bSee Table 2^c(i) Based on data that energy value of potato waste dry matter is equivalent to barley.

(ii) 2,000 lb of barley required to finish one steer or heifer in feedlot.

A processor-owned feedlot in the Maritimes has experienced difficulties in feeding potato wastes, apparently because of over use of wet potato wastes in the ration. The high price of grain, lack of supply of good quality feeder cattle and the relatively poor economics of commercial cattle feeding in the Maritimes also appear to be contributing factors.

(b) Hauled away by local feeder at no direct cost. This was the most common practice observed during the study. Feedlots visited that were obtaining their potato wastes in this manner included the McGregor Feedlot in Washington and Roslyn Park Farm Limited in Ontario, both discussed in Section 3. At the Ontario feedlot, wastes were trucked up to 100 miles at an estimated average freight cost to the feeder of \$4.50 per ton.

(c) Sold by the processing plant to local feeders. Sales of wet potato waste to feedlots have declined because of the difficult economic situation that has existed in the feedlot industry during the past two to three years. Cattle feeding has declined, with a resulting reduction in the demand for this product. In most instances, the amount charged for potato waste is equal to or only slightly greater than the freight costs required to deliver it to the feedlot.

4.3.2 Wet potato waste marketability evaluation

Using the definition developed in Section 4.1, the marketability of wet potato waste can be evaluated as follows.

(a) Product cost and value. There is no cost attributable to the production of wet potato waste, since it is a normal byproduct of the processing industry. There is a cost associated with waste solids recovery at the processing plant, but this is generally considered a pollution abatement cost and is more or less independent of the ultimate disposal of solids, be this by land fill or as cattle feed.

The price that feedlots are willing to pay for wet potato waste is influenced by many factors: 1) the feed value of the material; 2) the comparative cost of feed grains that the wet waste is replacing in the ration; 3) the cost of transporting the high moisture material to the

feedlot (this is very important as the cost on a dry matter basis is at least five times, and possibly as much as eight times, the cost based on wet weight); 4) the specialized equipment (see (b) and (d) below) that is required to switch from conventional to potato waste feeding; 5) the unique potential problems associated with feeding this material (see Section 3.2.1); and 6,) the higher level of management required to successfully feed this material. The net effect of these factors on the market price can be shown by the following example: the operator of the Roslyn Park Farms feedlot in Ontario stated that they would not use wet potato waste if barley was priced at \$1.50 per bushel or less. The cost of wet potato waste to the feedlot at that time was \$4.50 per ton and barley was approximately \$2.50 per bushel. Assuming a dry matter content for the potato waste of 18%, and for the grain of 90%, the dry matter was costing \$25.00 and \$133.00 per ton for potato waste and grain, respectively. At \$1.50 per bushel for barley the dry matter would cost \$80.00 per ton, which is approximately three times the present cost of dry matter from the potato waste. It was at this relationship between the price of barley and potato waste that this producer felt that the inclusion of wet potato waste in the ration would not be justified.

(b) Ease of handling. The physical characteristics of the product, principally its slurry form, make specialized storage facilities and conveying equipment necessary at the feedlot and this is a restriction to its marketability in the case of an existing operation. However, if the drier portion of the wastes (culls, trim waste, etc.,) alone is being used, then there may be no special handling requirements.

(c) Continuity of supply. Interruptions in the supply of wet potato waste are not major restrictions to the marketing of this product since most feedlots keep two to three months supply on hand to cover such periods.

(d) Ease of distribution. Distribution is extremely difficult due to the high moisture content and the requirements for specialized shipping equipment. As with handling in general, transport of the drier portion of the wastes, if separated, does not require specialized equipment.

(e) Consistency of product quality. Although the consistency of the potato waste product can vary from plant to plant, this normally is not a problem if the feedlot is obtaining a more or less consistent mixture from one plant or a number of plants and is providing large enough storage to even out day to day variations. Changes in dry matter, pH, etc., during storage can create problems unless the operator fully understands the material and the various changes that can take place.

(f) Limitations of use. Limitations of use include: best results only when fed to feedlot cattle over 700 lb; pH must be reduced prior to feeding; the low dry matter restricts the amount that can be included in a ration; the relatively high sodium content can restrict inclusion in rations for certain classes of livestock; and, possibility of pesticide residues (from the potato crop) precludes its use in dairy cattle rations.

(g) Product life. If properly stored the product is fairly durable; however, losses in dry matter are a common occurrence during storage.

4.4 Marketing Dried Potato Waste as a Feedstuff

Dried potato waste is presently being marketed by the Pillsbury Company and Tater Meal Co. Since these are relatively new operations, there is limited information available on the marketing of this product. The product from the Tater Meal plant is produced in bulk and shipped by rail to feed mills up to 300 miles from the plant. These feed mills combine it with other ingredients to produce rations for livestock.

Using the definition developed in Section 4.1, the marketability of dried potato waste can be evaluated as follows:

(a) Product cost and value. Tater Meal Co., of Presque Isle, Maine, stated that product cost to the end user must remain below 75% of the price of corn or barley. Product priced above this level does not compete with corn or barley as a feed ingredient.

(b) Ease of handling. Tater Meal's physical appearance has been described as a "brown gritty powder or sand". Tater Meal Co. stated that they have had no problems with "flowability" or bridging in bulk bins. It does appear, therefore, that the product can be handled in bulk, but this should be considered by both the producer and feed manufacturer. The

potential loss of product occurring during handling should also be considered because of its relatively small particle size.

(c) Continuity of supply. A manufacturer of dried potato waste is fully reliant on the potato processor for his supply of raw material and, since potato processors sometimes shut down because of poor market conditions or a poor season's supply of potatoes, the availability of the dried product may be interrupted.

An example of this is the Pillsbury potato waste meal plant in North Dakota, which was shut down for two months last winter because potato processors were not operating because of poor marketing conditions. This lack of continuity of supply can have an adverse affect on the marketing program for dried potato waste.

(d) Ease of distribution. The physical properties of the meal would allow for bulk movement comparative to that of feed grains.

(e) Consistency of product quality. As indicated in Section 3.2, potato waste should be considered primarily as a source of energy and not protein. It should be possible to maintain energy levels of dried potato waste comparable to those of feed grains.

(f) Limitations of use. At present, indications are that dried potato waste meal should only be used as an ingredient in ruminant feed rations, i.e. cattle and sheep.

If the material is of very fine particle size the problem of bloat could limit its use in ruminant rations.

It does not appear feasible to pellet a ration containing more than 33% potato waste by weight, since the steam tends to form a paste with the starch that is present. However, potato waste has been used at a level of 15% by weight of the final ration and was found to enhance the binding of the pellet.

There may be limitations in feeding this product to dairy cattle because of the possibility of pesticide residue from the original potato crop contaminating the milk.

(g) Product life. Dried potato waste should be as durable as feed grains in storage, where perishability is governed by moisture content.

4.5 Summary

If potato waste is to be included as an energy source in rations for beef cattle, it must be able to compete with other feed ingredients in the market place. Conventional energy feedstuffs in Canada are primarily produced in the Prairie Provinces and shipped to the grain deficient regions of the country. In the grain deficient Maritime region, potato waste could provide an alternative to western feed grains as a source of energy for beef cattle. In New Brunswick, potato waste could supply over 90% of the energy in rations for cattle on feed. However, since these cattle are held in small numbers, the use of wet potato waste, because of the specialized handling procedures required, is not feasible. Dried potato waste, however, would not suffer from this limitation.

5 DRYER SYSTEM FOR POTATO WASTES

5.1 Introduction to Drying

5.1.1 Fundamental considerations

For the purpose of this discussion, drying means the removal of moisture from a solid by heat.

In the drying operation, two processes are involved: 1) transfer of heat into the material, 2) transfer of mass, usually water, out of the material. The former may occur by means of conduction, convection, or radiation and in some dryers is a combination of these. The latter depends on liquid or vapour movement to the surface of the solids, which is a function of the internal physical characteristics of the solid and its initial moisture content, and then vapour transfer from the surface, which is a function of external temperature, area of exposed surface, air humidity and air flow. The rate at which drying proceeds is governed by these two processes.

The energy required to carry out drying is related to the amount of heat required to raise the temperature of the wet material (sensible heat) and the amount of heat required to evaporate the liquid water (latent heat). The latent heat for water is approximately one thousand Btu's per pound of water evaporated.

The thermal efficiency of a dryer is the theoretical heat, composed of both sensible and latent heats of water, required to remove moisture, compared to the actual heat delivered. Expressed as a percentage:

$$\text{Thermal efficiency} = \frac{\text{Theoretical Heat Required}}{\text{Actual Heat Delivered}} \times 100.$$

The heat required to raise the initial temperature of the solids in the feedstock to the temperature at discharge is considered part of the heat loss, along with the losses from radiation, convection, and conduction to the surroundings. A major heat loss in some types of dryers is contained in the exhaust gases.

5.1.2 Types of dryers

Drying technology covers a very broad spectrum of industrial applications. Thus, there are numerous types of dryers on the market, some extremely specialized and, in general, more expensive, and other more rudimentary in application. The following list provides an overview of the common, and some not-so-common, types of dryers:

- (a) Tray or cabinet dryers. These are generally limited to relatively small product capacities on a batch basis.
- (b) Conveyor dryers. Material is transported through a heated chamber or tunnel on a conveyor. Depending on the material being dried, the conveying system may consist of a steel band, perforated band, series of cylinder rollers, or a vibrating band. Generally, long residence times are required for drying high moisture material.
- (c) Turbo-tray dryers. Gentle spreading and turning of material occurs in this elaborate modification of a tray dryer.
- (d) Vacuum tray and vacuum freeze dryers are specialized dryers used with heat sensitive materials; freeze drying is used where the qualities of flavour and smell are to be preserved.
- (e) Agitated pan dryers are used for small batches of material where gentle agitation enhances drying.
- (f) Infrared dryers are used where relatively low amounts of moisture are to be removed. Heating is by radiation.
- (g) Dielectric dryers. Material is heated in a high frequency electric field. Equipment is very expensive and few applications justify cost.
- (h) Indirect rotary dryer. This dryer is used where contact of material with combustion gases is to be avoided, for heat sensitive materials, and for instances where dust losses are liable to be high. Typical feedstocks include maize germ and apple pomace.
- (i) Fluidized bed dryer. This is a specialized dryer in which materials floats on a bed of air. Agitation can be controlled to prevent attrition and breakage of material.

(j) Superheated steam dryers have a very high thermal efficiency but have had limited application because of a lack of suitable equipment. New developments in technology may give a wide application to this type of dryer.

(k) Spray dryer. Feedstock, from liquids to pastes, is atomized by special nozzels or rotating discs and sprayed into a high temperature drying chamber.

(l) Direct rotary dryer.

(m) Sonic dryer.

(n) Double drum dryer.

(o) Flash dryer.

(p) TorusDisc dryer. Trademark - Strong Scott Mfg. Co.

Dryer types (l) through (p) above will be discussed in further detail in Section 5.2.2.

5.2 Potential Drying Systems for Potato Wastes

5.2.1 Criteria for selecting dryer types

Preliminary selection of suitable dryer types involved consideration of the following:

(a) Nature of the material to be dried. As discussed in Section 2, the characteristics of potato wastes vary within the industry with different product requirements, process components, and waste handling components. In general, however, once the recovered wastes are mixed together, they are fairly similar, in the form of a slurry containing 12-18% solids. The high viscosity and sticky nature of these slurries, especially after size reduction of large pieces, are of prime importance in selecting a suitable dryer and the conditions under which it is to be operated.

The gelatinous waste from dry caustic peelers requires special handling; if it composes a high percentage of the waste mixture, the number of drying options may be restricted.

(b) Assurance of dried feed quality. Attrition of particles should be minimized so that the dust content of the dried feed represents neither a handling problem nor a potential source of bloat in cattle.

(c) Air pollution. The emission of particulates, smoke, and odours from a drying installation must conform to pollution control regulations. It is, therefore, imperative that the evaluation of dryer types include an awareness of the potential severity of air pollution problems, so that abatement procedures, either by modified operation or pollution control equipment, are properly implemented. Scorching and burning of the product is to be entirely avoided because smoke, and possibly odours, produced will necessitate after burner equipment that is expensive to install and operate. Particulate emissions, attendant dryers where the material being dried is showered through the gas stream, can be controlled by cyclones, in conjunction with baghouses or wet scrubbers if necessary.

(d) Drying of other materials. Equipment versatility to dry other materials, especially wastes emanating from other food and beverage processing industries, could be a marketing advantage in those regions where cost sharing between a number of plants results in a more viable operation. Other materials might include brewers' spent grain, brewers' yeast, apple pomace, beet pulp, whey, etc.

(e) Costs. Two benefits are derived from the drying of potato waste: 1) production of a saleable animal feed, and 2) contribution to the pollution abatement program of the processing plant. The costs should be spread over these two benefits. To encourage the use of waste products in this manner, however, drying must be carried out as economically as possible. High capital cost dryers obviously should not be considered for the production of a comparatively low value product. Dielectric, fluidized bed, and vacuum dryers fit into this category. The cost of fuel is the major operating expense and, therefore, thermal efficiencies are very important in the selection of dryer types. Thermal efficiencies, however, are not fixed for any dryer type, but are dependent on specific design features, operating conditions, and properties of the material being dried.

5.2.2 Description of selected dryer types

Five dryer types appear to be applicable for drying potato processing waste solids. These are the direct-fired rotary, sonic, double drum, flash, and TorusDisc dryers. However, only one, the direct-fired rotary, has and is being used for this purpose. Another, the sonic, has had a short test run at drying dry-caustic peel waste. As far as is known, the other three types have not been used to dry potato processing wastes, but are included in this discussion because they represent types that may have application with this type of material. Short pilot studies or, at the minimum, manufacturer's test runs, are necessary to verify whether any of these last three dryer types actually have drying potential with potato processing wastes.

(a) Direct-fired rotary dryer. The rotary dryer consists of a rotating cylinder, inclined slightly from the horizontal. Wet material is fed into one end of the cylinder and the rotating motion, coupled with the inclination of the system, causes product discharge from the opposite end. As the dryer is rotated, flights on the interior surface of the shell lift the wet material and shower it through the hot air. This flow of hot air usually constitutes the heating medium which supplies the required sensible and latent heat of evaporation to the moisture. It acts also as a medium for the removal of water vapour formed in the vicinity of the evaporating surface.

Various designs of the direct rotary dryer are on the market. These can involve either parallel or counter flow of heated gases and the material being dried; various internal flight designs; and, a single or multipass cylinder design.

A diagram showing the basic components of a rotary dryer is shown in Figure 4.

The rotary dryer is used in the dehydration of many different products, including alfalfa, brewers' spent grain, and poultry manure. With high moisture materials, such as potato waste slurry, the dried product must be recycled and mixed with the raw feedstock prior to entry into the cylinder. This recycling is necessary to prevent the waste from sticking to the walls of the dryer, which can result in a burned and scorched product.

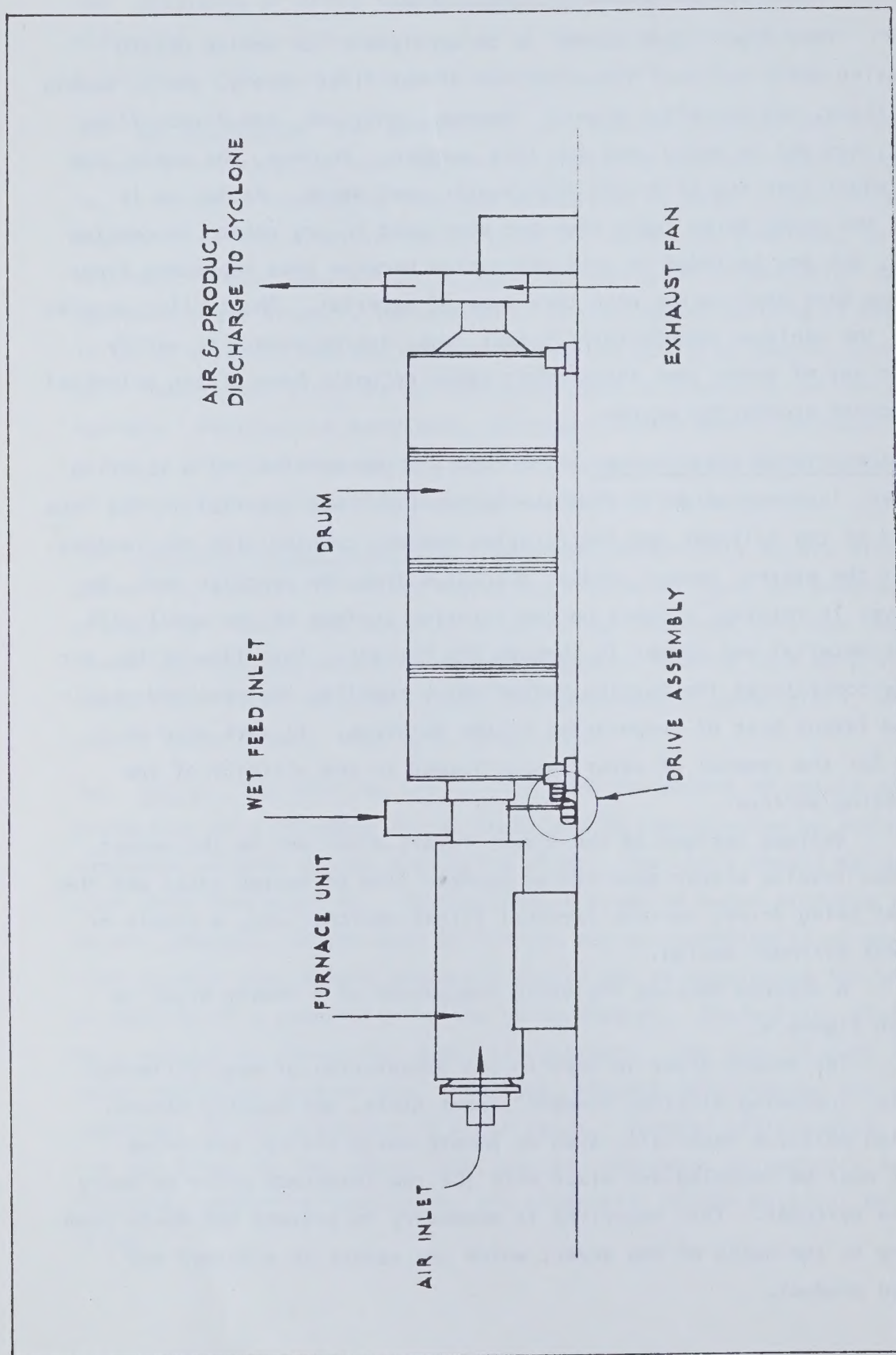


FIGURE 4. DIRECT-FIRED ROTARY DRYER

As with other direct-fired dryers where solids are showered or sprayed through heated gases, the control of particulates in stack emissions is of concern. Particulate carryout with the exhaust gases is related to the particle size of the dried material and the velocity of the exhaust gases. Thermal efficiencies typically vary between 30-70%.

Details of the use of the direct-fired rotary dryer for drying potato wastes are presented in Section 5.3.1.

(b) Sonic dryer. In the sonic drying process, the feedstock is atomized and dried by the pulsating flow of a stream of hot gases produced by a resonating jet combustor. Large quantities of secondary air are entrained by the combustor which effectively acts, then, as a heater-blower unit. The jet combustor, shown in Figure 5, consists of a hollow "U" tube wherein fuel is ignited, with the production of resonating combustion gases. The feedstock is injected into the exhaust end of the combustion tube where it is quickly atomized into fine particles by the very high turbulence and simultaneously subjected to a high temperature ($3,000^{\circ}\text{F}$). Partial drying occurs in the combustor; residual drying occurs at low temperature ($200\text{-}400^{\circ}\text{F}$) in the dryer chamber to which the combustion gases, air, and solids are discharged. Figure 10 in Section 5.3.2 shows the details of a sonic drying plant.

The advantages of the sonic dryer have been cited by others [9].

- 1) It is simple to operate.
- 2) It is simple to construct, having few moving parts other than feed pumps, feed preparation mills and fans.
- 3) It handles difficult materials such as sludges, pastes and oily materials.
- 4) It has a short residence time, which is desirable for heat-sensitive materials.
- 5) It has a high degree of turbulence inside the jets and the dryer body, leading to good heat transfer.

The principal disadvantage is the high noise level of the jets and the attendant vibrations. Substantial sound proofing may be required for environmental acceptability as well as worker health. Structural design of any housing components must take into account the additional stress caused by the vibrations.

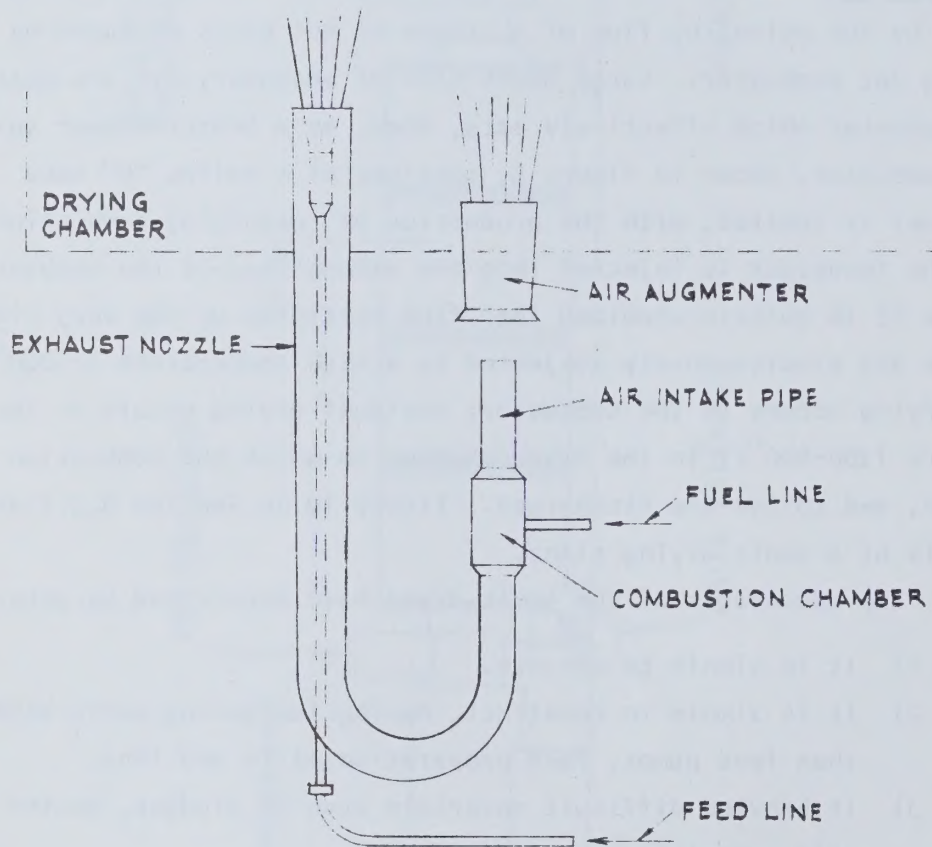


FIGURE 5. SONIC DRYER JET COMBUSTER

As with the rotary dryer, particulate carryout with exhaust gases is liable to be high and must be controlled.

The sonic dryer has the potential for drying a wide variety of high moisture and high oil content materials and, because of the nature of the drying process, the same facility may be readily adapted to multiple products.

Thermal efficiency for the sonic dryer is not well documented, but the evidence available suggests that it is comparable to other direct-fired dryers.

(c) Double drum dryer. Drum dryers are also referred to as flake dryers or roller dryers. In a drum dryer, the drying effect is obtained by the transfer of heat from a heating medium within a hollow rotating cylinder. The material is dried on the drum surface by conduction. In some cases, a forced convection air current is applied to the surface.

The double drum dryer consists basically of a feed pipe that discharges the liquid material over two heated drums. These chrome-plated drums of cast iron or steel are usually steam heated. The evaporation of the water occurs during a partial revolution of the drums. A common variable speed drive is used to regulate the speed of the drums. This controls the contact time between the wet material and the surface of the drum. The dry material is then scraped from the drum by a stationary knife onto a conveyor. A vapour hood is used to remove the water vapour from the working area. The components of a double drum dryer are shown in Figure 6.

Some of the applications for double drum dryers are for the drying of solutions, slurries, and solid suspensions in water. They are used in the processing of potato flakes.

The single most important step in evaluating the double drum type of dryer is determining whether the feedstock will form an adequate and uniform film on the drying drum. Once this has been established, further pilot studies are required for the design of a dryer to match the particular application.

Thermal efficiencies as high as 80% have been reported when special attention is given to the insulation of the drum ends. In general, though, efficiencies are comparable to those of rotary dryers.

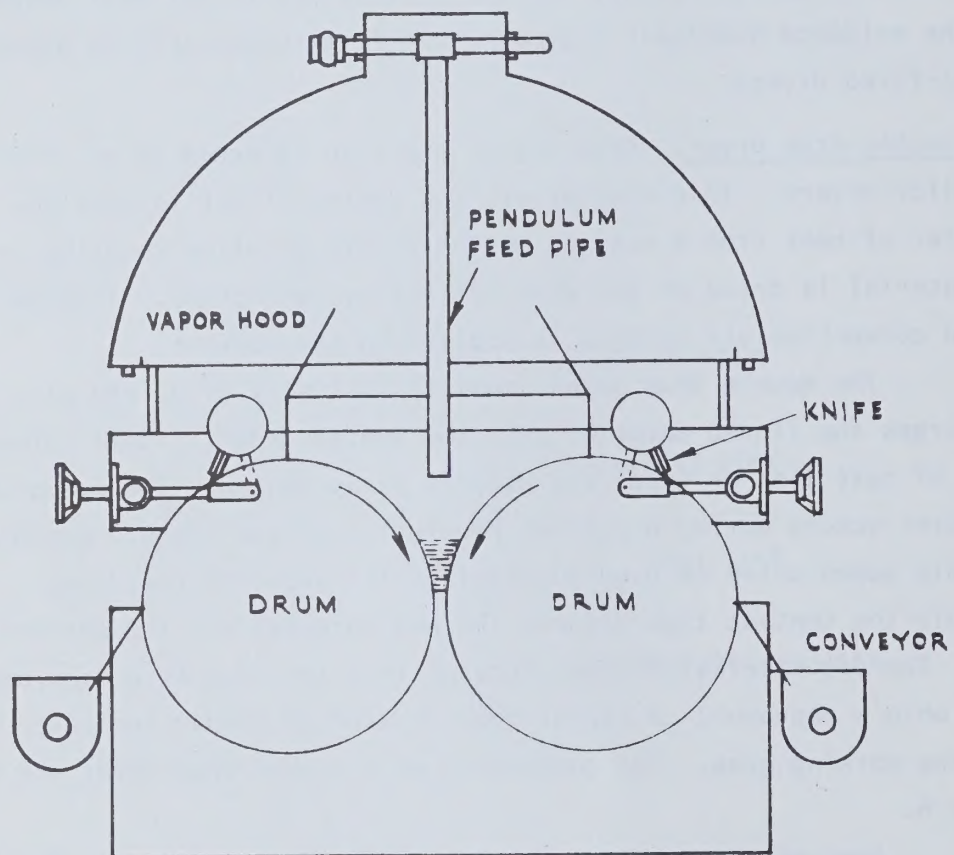


FIGURE 6. DOUBLE DRUM DRYER

In this type of dryer there is little opportunity for particulate contamination of the exhaust air and, therefore, air pollution is not a problem.

(d) Flash dryer. Flash dryers are also known as pneumatic or air lift dryers. The major components in a flash dryer are: a source of hot gases; a material feeding device; a main drying column; a cyclone for material-air separation; and, an air exhaust fan (see Figure 7). Drying is accomplished in a few seconds as the solids are conveyed up the drying column in contact with hot gases, which are at an initial temperature of 1,300°F. The material must be reasonably free-flowing and of small particle size to ensure proper conveyance and drying.

For the drying of a high moisture, sticky material, such as potato processing wastes, recycle of the dry product to the feed is necessary to lower the moisture content and produce favourable material flow.

Flash dryers are presently used in the production of potato granules. However, this application cannot be directly related to potato processing wastes because, along with other factors, the feedstock in the case of granule production is precooked, which may enhance moisture release during drying.

Air pollution control requirements are similar to those for the direct-fired rotary and sonic dryers.

(e) TorusDisc dryer. The TorusDisc dryer is a newly developed conduction dryer with mechanical agitation of material that provides for continuous drying of solids, slurries, and viscous materials. The dryer consists of a stationary horizontal vessel with a tubular rotor on which are vertically-mounted double-walled discs of a hollow doughnut configuration. Heating surfaces include the discs, rotor shaft, and inner wall of the vessel.

Product to be dried is transported in an axial direction through the annular space between the discs and the vessel toward the discharge end. Some degree of backmixing, if required for wet non free-flowing materials, can be obtained within the vessel itself.

Although knowledge of the current use of this dryer is extremely limited, the TorusDisc dryer has the following advantages: reputed high

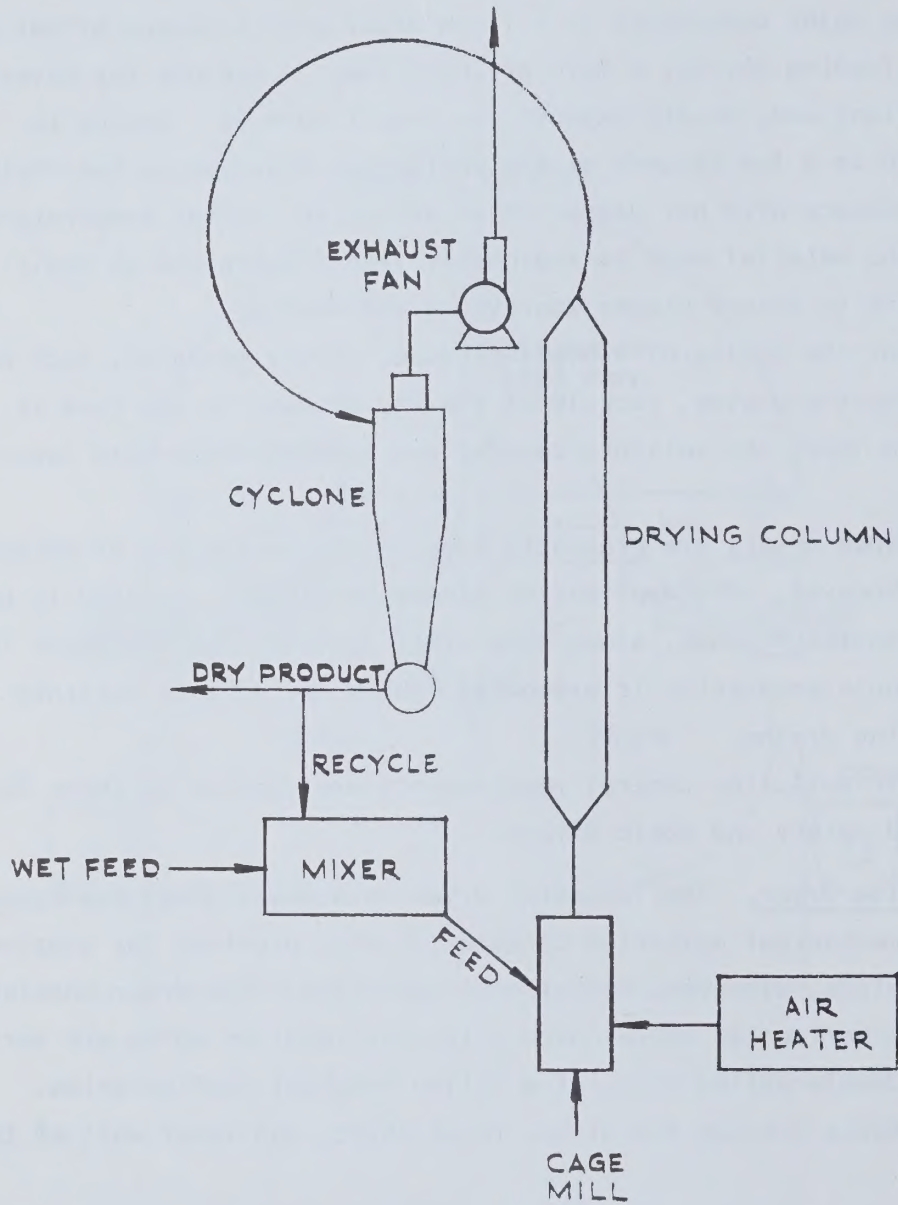


FIGURE 7. FLASH DRYER

heat transfer coefficients; low expected maintenance costs due to the slow speed of the rotor; and, like other indirect-fired dryers, low air pollution potential.

The TorusDisc dryer is shown in Figure 8.

5.3 Systems Presently Used for Drying Potato Wastes

There has been limited experience with drying potato wastes in North America. The experience that does exist is primarily associated with the direct-fired rotary dryer, which has proven commercially operational in about half of the cases seriously attempted. Recently, the sonic dryer has been investigated for this use and the initial results suggest high potential. Other high moisture materials, such as animal wastes, are presently dried commercially using the direct-fired rotary and sonic dryers.

5.3.1 The direct-fired rotary dryer

The following background information was assembled through a series of field trips, mail correspondence and interaction with equipment suppliers.

There have been five or six serious attempts to use rotary dryers to dehydrate potato wastes.

In 1966, Tater Meal Co. was established in Presque Isle, Maine, to produce and market dried potato waste. Three brothers, Bernard, Owen, and Charles Estey, set out to develop a drying system using a Heil dryer. After a lengthy trial and error period, a process was developed and then patented. This dryer plant operates today and is likely the most successful case to date. Details of this particular installation will be given later in this section as the illustration for the direct-fired rotary type of dryer.

The next attempt occurred in Crookston, Minnesota, where the Red River Alfalfa Co. successfully dried potato waste in the Heil rotary dryers used to dehydrate alfalfa. The Maine experience was used in the development planning for the modification of this dryer plant. Production was carried out during the part of the year when alfalfa was not available with a capacity of 48 tonnes of dried potato waste per day. Although the production was by Red River Alfalfa Co., the marketing was carried out by the Pillsbury Co. In later years, principally due to the high cost of

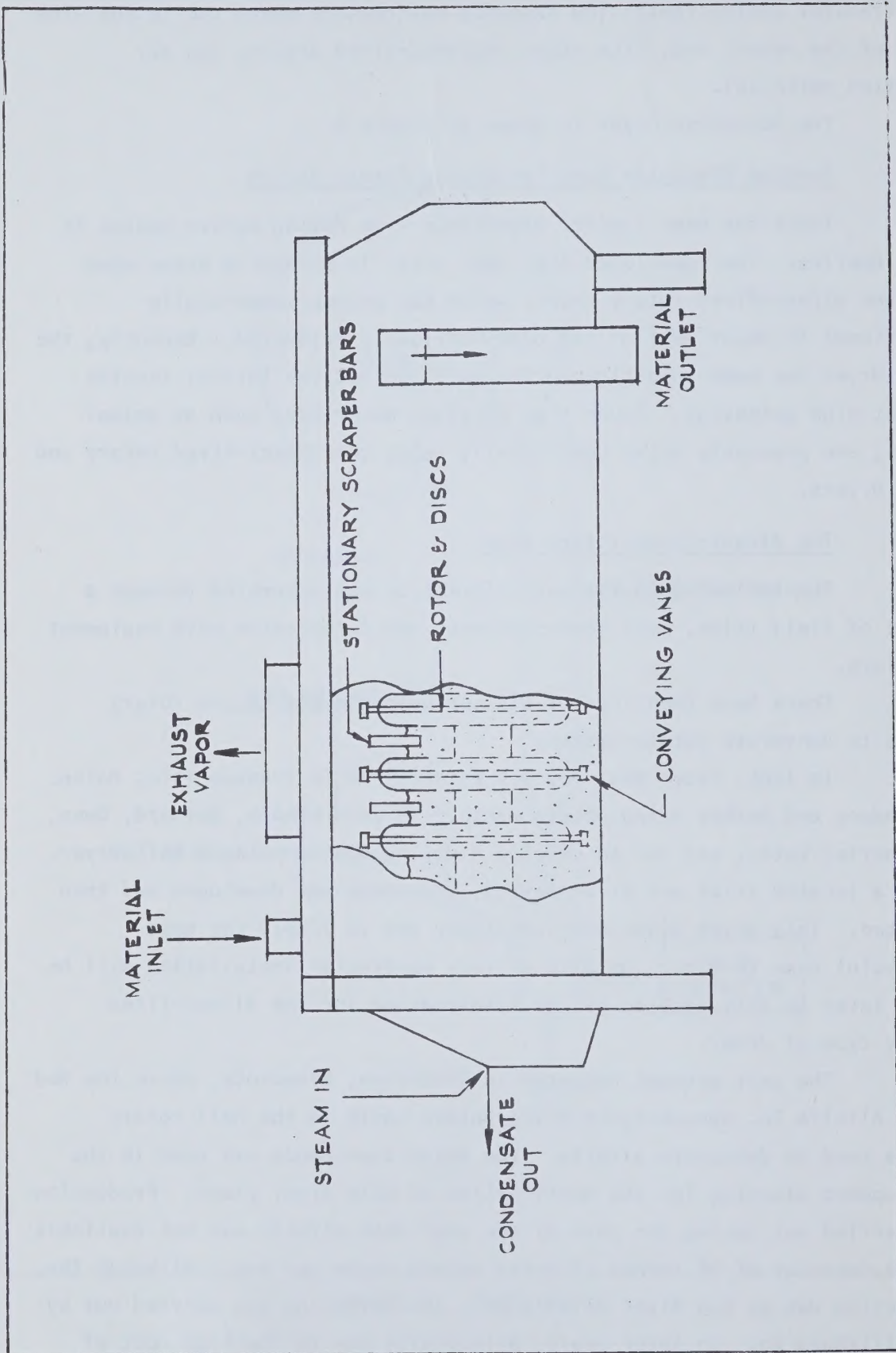


FIGURE 8. TORUSDISC DRYER

propane, on which the plant operated, Red River Alfalfa Co. ceased their potato waste drying operation and Pillsbury established a drying plant in Grand Falls, North Dakota, about 20 miles from the Red River facility. The development of this plant also involved the experience gained at the Tater Meal plant in Maine. The Pillsbury plant has been operating for a couple of years, with a production capacity of about 10,000 tons of dried product per year.

Salada Foods attempted to dry potato wastes in Ontario, but the attempt has been abandoned.

Other major attempts to use the rotary dryer were made by two large potato processing concerns: J.R. Simplot in the western United States, which carried out a full scale test study over a two-year period with a Stearns-Roger rotary dryer; and McCains in eastern Canada, which carried out a similar full scale test study over about the same length of time using D.B. Vincent equipment. Both experiences provided research results, but both attempts were abandoned.

The following is an illustration based upon the Tater Meal Co. installation in Presque Isle, Maine, and draws upon information gained from a field visit to the facility, including a discussion with the owner-developer, and upon technical input from the patent description (956170-Canada) and the equipment suppliers for the facility.

This dryer system was developed solely to dehydrate potato waste material.

(a) System elements - general description. Potato waste is trucked to the drying facility and deposited in receiving bins according to waste type. The various components are then blended and masticated. Hydrated lime and recycled dried product are mixed into this wet waste prior to being fed to the dryer for dehydration. As the dried product exits from the dryer, it is conveyed through two cyclones for solids-air separation and for product cooling. The operation is monitored and regulated from a central control panel.

A flow diagram for the Tater Meal plant is given in Figure 9.

(b) System elements - detailed description.

Waste feed input

Waste Receiving Component - The various types of potato waste

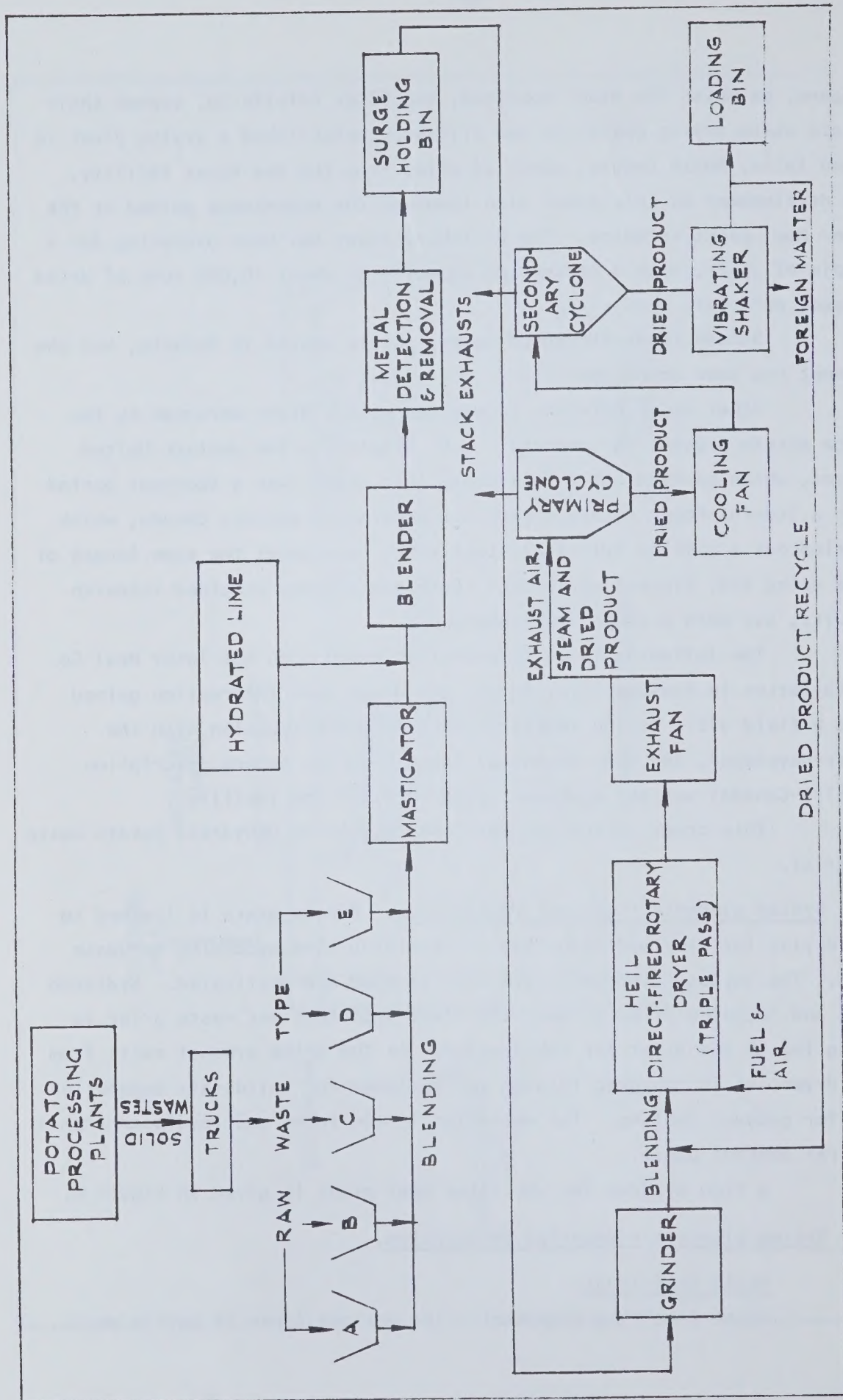


FIGURE 9. FLOW DIAGRAM - DIRECT-FIRED ROTARY DRYING SYSTEM AT TATER MEAL CO., PRESQUE ISLE, MAINE

product are trucked from processing plants and deposited in separate product-type receiving bins, namely; (A) lye peel, (B) filter cake, (C) waste cooked products including french fries, (D) cull potatoes, and (E) screenings (see Figure 9). Very high moisture content slurries are not accepted. Since the wastes are supplied from several processing plants, an averaging effect occurs in each bin.

Transfer and Blending Component - A predetermined mix from the various raw product bins is fed into a transfer screw auger. This mixture is maintained at a moisture content between 75% and 90%, with the lye peel component making up less than 25% of the total. Blending occurs as the material is conveyed to the masticator.

Mastication - The feedstock is transformed into a homogeneous mixture with conventional mastication equipment.

Transfer Component - The potato feedstock moves by screw conveyor from the masticator to a blender.

Hydrated Lime Input - Hydrated lime is added to the feedstock on its way to the blender. The amount added yields a final dried product containing between 4% and 9% calcium by weight.

Blending Component - The lime-potato mixture is thoroughly blended.

Metal Detection - The feedstock is passed through a metal detector where any stray metal is removed.

Surge Holding Bin - The material is screw augered to a surge holding bin. (The mixture, at this point, is no longer sticky, due to the action of the lime that was added.)

Grinder - The feedstock is conveyed to a hammer mill for grinding.

Recycled Dry Product Input - As the feedstock is conveyed to the dryer, dried product is added to the wet feedstock to reduce its moisture content to between 60% and 65%.

Air input

Air for combustion and drying is drawn through the furnace and dryer units by a 100 hp fan located at the exhaust end of the dryer.

Fuel input

Bunker C heating oil is electrically heated prior to being injected into the furnace unit located at the inlet end of the dryer.

Drying process

The feedstock enters a Heil model no. 105-32 dryer. In this triple pass (three concentric drums) type rotary dryer, the material moves through a horizontal distance equal to three times the length of the drum. The material is agitated and sprayed through the hot air stream by flights on the surfaces of the drums. The feed rate is adjusted according to the desired moisture content of the end product. Dryer operating temperatures range from 900°F to 2000°F (normally 900°F to 1200°F) at the dryer inlet and 200°F to 250°F at dryer outlet.

Product output

Primary Cyclone - The dried product is advanced by the exhaust fan to a cyclone where solids-air separation occurs.

Product Cooling - A fan conveys dried product from the bottom of the primary cyclone through a cooling duct to a secondary collection cyclone. Product temperature is lowered to between 70°F and 95°F.

Vibrating Shaker - The cooled product passes over a shaker to remove agglomerated product or any foreign matter.

Product Destination - A portion of the dried product is recycled to be mixed in with the wet feedstock; the rest is conveyed to storage where it is off-loaded in bulk form.

Exhaust gas output

Exhaust air and steam is released to the atmosphere from the cyclone stacks. The quantity of particulates in the stack emissions is not known.

(c) Quantitative description.

Nominal rating

This dryer facility has a nominal evaporation capacity of 30,000 lb of water per hour, divided equally between two Heil model no. 105-32 dehydrators.

Unit capacity

There is little recorded performance data for this installation, so the following is a hypothetical example based on the patent description, operator input, and manufacturer input.

Assume a one ton input of raw feedstock (composition: 60% cull potatoes, 20% reject french fries, 5% screenings, and 15% peel waste) with a moisture content of 85%. To this, 66 pounds of hydrated lime at a moisture content of 7%, and 689 pounds (25% of final feedstock weight) of dried product at 7% moisture content, are added. This final feedstock has a moisture content of about 64%, which falls within the desired range of 60% to 65%, and a total weight of 2755 pounds.

Output from the dryer at 7% moisture weighs 1077 pounds; 689 pounds of this, or 64% of the output, is recycled. The remaining 388 pounds (including the lime added) goes to product storage.

Water evaporated in this example, therefore, is equal to 1678 pounds.

Using the nominal rating for this installation of 30,000 pounds of water evaporated per hour, the hourly feed input and product output capacities can be calculated as follows:

$$\text{Raw feed input: } \frac{30,000}{1678} \times 2000 = 35,757 \text{ lb/hr}$$

$$\text{Product output to storage: } \frac{30,000}{1678} \times 388 = 6,937 \text{ lb/hr}$$

Energy conversion

Energy theoretically required to evaporate 30,000 pounds of water @ 245°F:

$$35,000,000 \text{ Btu/hr.}$$

Energy expended (fuel only) to evaporate 30,000 pounds of water based on manufacturer's input of 1892 Btu/lb is:

$$56,760,000 \text{ Btu/hr.}$$

Thermal efficiency:

$$\frac{35.0}{56.6\%} = 61.6\%$$

Facility capacity

Based on an operating day of 16 hours (actual operating day varies from 10 to 24 hours) and 250 days/year operation, the production capacity of this facility is about:

14,000 tons/year.

5.3.2 The sonic dryer

The sonic dryer is a recent development which has had limited industrial use to date. The following history of system development is based on information contained in a report prepared for Sonic Drying Systems Limited of British Columbia, by B.H. Levelton and Associates Limited of Vancouver, entitled "A Report on the Operation of the Resojet Dehydration System For the Production of Dried Poultry Waste".

Pulse jets were used in "buzz-bombs" in World War II. Hiller Aircraft Co. of California researched the use of the pulse jet for aircraft in the late 1950's, and also investigated its use as a heater-blower for drying.

Litton Industries of California acquired rights from Hiller Aircraft in mid 1960's and developed the Resojet drying system.

A sonic drying facility was constructed in Stephenville, Newfoundland for producing fish meal, and operated for short periods in 1968 and 1969 before being abandoned.

A second installation was built at Turlock, California in 1970 for producing mink feed from poultry viscera.

In 1971, Sonic Drying Systems Ltd. acquired the development rights from Litton Industries. Test runs with other feedstocks were carried out from time to time at the Turlock facility. In 1974, the Turlock Facility was moved to Roy, Washington where it was modified to the present system for drying poultry manure. Commercial operation started in October 1975.

The following illustration is based on the facility at Roy, Washington and draws upon information gained from a visit to the facility, a discussion with the owner-developer, the patent description for the process (3,618,655 U.S.), and the report by Levelton and Associates.

This dryer plant, located on a poultry farm owned by Wilcox Farms Inc., dehydrates the manure from laying hens. On occasion, other materials are brought to the plant for test runs. A short test run using pure dry caustic potato peel waste has been carried out. Based on the apparent success of this test, and the system's known capability with high moisture feedstocks, the sonic dryer shows good potential for application with potato processing wastes.

(a) System elements - general description. Fresh poultry manure is trucked from the hen houses to the drying facility and dumped into a receiving bin. This wet waste is transferred to a disintegrator, where it is made into a uniform paste before being pumped to the sonic dryer. The dryer is operated at a constant fuel input and a variable feedstock input. The dried product exits both from the bottom of the drying chamber and with the exhaust gases. Solids-air separation of the exhaust output occurs in two cyclones; the dried product is transferred to storage; the air is exhausted to the atmosphere after passing through a wet scrubber. The entire drying operation is monitored and regulated from a control panel.

A flow diagram for the facility appears in Figure 10.

(b) System elements - detailed description.

Waste feed input

Waste Receiving - Wet waste is dumped into a Heil automatic chopped forage feeder equipped with a lift apron.

Transfer Component - A screw conveyor carries the material from the receiving unit to the disintegrater.

Disintegrator - Material passes from the screen of a hammer mill (Rietz RD 18) into a ribbon mixer which outputs a relatively uniform paste.

Transfer Component - The material moves in a screw conveyor to a positive displacement vane pump.

Feed Pump - This Autio pump, which is connected to the screw conveyor shaft, feeds the dryer. The feed rate is controlled by a variable speed drive.

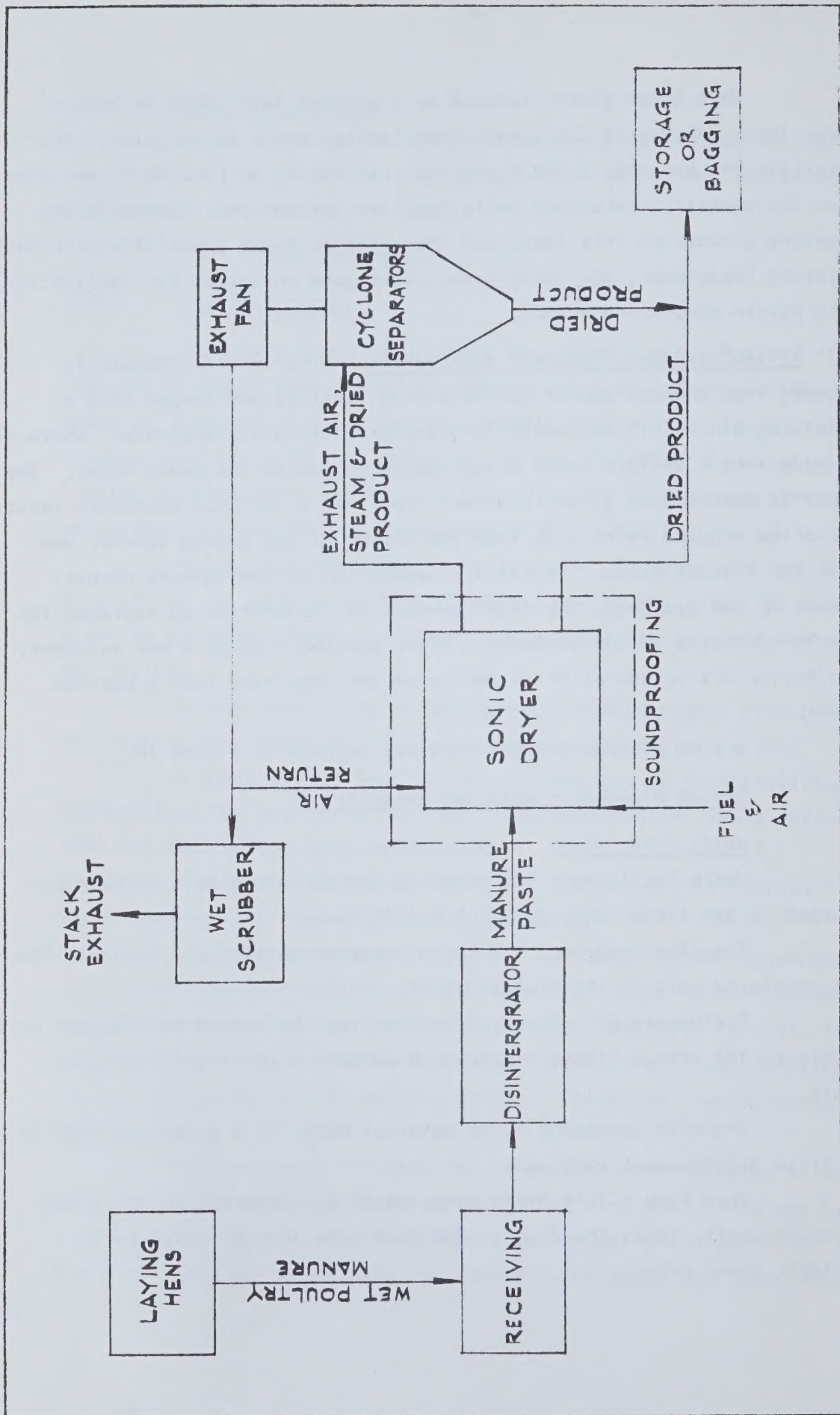


FIGURE 10. FLOW DIAGRAM - SONIC DRYING SYSTEM AT WILCOX FARMS, ROY, WASHINGTON.

Transfer Component - The material is pumped through a 3/4 inch pipe to a position inside each of the injection nozzles of two large jet combustors. (See Figure 5.)

Resojet Combustors - These jets, which are located under the drying chamber, are used to inject waste material into the drying chamber.

Air input

Vents - There are vents in the concrete block walls, which enclose the bottom portion of the drying chamber and the jets, that supply air to the jets.

Recirculated Exhaust Gas - A portion of the exhaust gas is recirculated back to the area of the jets.

Fuel input

Fuel Lines - Fuel lines lead to injection ports located within the jet combustor.

Fuel - No. 5 fuel oil (diesel) is presently used as the operating fuel; propane is used in startup.

Dryer component

Resojets - Five jet combustors supply heated air and sonic energy to the drying chamber. (See Section 5.2.2 for description of drying process.) Three small jets are located around the periphery of the bottom of the drying chamber, positioned at an incline to both radial and vertical axes; two large jets, through which waste feed is injected into the drying chamber, discharge vertically upward through the bottom of the chamber.

Drying Chamber - The drying chamber is of steel construction and is about seven feet in diameter and twelve feet high.

Sound Proofing - The bottom portion of the drying chamber is enclosed in a concrete block structure; the top portion in a shell filled with sound insulating material. Other surfaces are covered with lead sheeting to help deaden noise levels.

Product output

Drying Chamber - A portion of dried product, estimated at 60% of the total, exits through a port in the bottom of the drying chamber.

Cyclones - There are two cyclones which separate product from the exhaust gas. These cyclones are approximately seven feet in diameter. It is estimated that 40% of the dried product exits with the exhaust.

Transfer Components - There are two sub-branch conveyors, one collecting material from the bottom outlet of the drying chamber, and the second collecting material from the bottom outlet of the cyclones, which feed a main collector conveyor that carries the product to storage.

Bagging Machine - Product may be directed to a bagging machine or returned from product storage to the bagger.

Product Storage - Storage is so constructed as to enable loading of bulk product to trucks.

Exhaust gas output

Exhaust Fan - Gas is transferred from the cyclones to a wet scrubber, with additional energy input provided by an exhaust fan. This unit is driven by a 50 hp motor.

Recirculation Bypass - A portion of the hot gas is diverted and returned to the area of the jet combustors.

Wet Scrubber - The remaining portion of the exhaust gas is subjected to a wet scrubber which removes particulate matter and some water soluble odour components prior to release to the atmosphere. The quantity of particulates in the stack exhaust is not known.

System operation

Resojets - Each of the five jets are independently started using propane. A spark plug located in the combustion chamber of the jet combustor is used for ignition purposes until the jets are warmed up sufficiently to maintain self ignition. Once warmed up, the fuel is switched to diesel. The jets are operated at a fixed fuel input.

Feed Input - The poultry manure feed input is varied in order to maintain proper dryer outlet temperature and moisture content of dried product. The system operates continuously without feed rate adjustment after the initial setting, unless the moisture content of waste feed happens to vary substantially from one truck load to the next.

(c) Quantitative description.Nominal rating

This dryer has a nominal energy rating of 14,000,000 Btu/hr, distributed between two large jets at 4,000,000 Btu/hr each and three smaller jets at 2,000,000 Btu/hr each.

Unit capacity

The following figures are based on actual results from a one-hour test carried out by B.H. Levelton and Associates in 1975:

Feed - 8430 lb of wet poultry waste at a moisture content of 75%,

Product - 2470 lb of dried poultry waste at a moisture content of 13%,

Water Evaporated - 5960 lb.

Energy conversion

The following figures are based on the same one-hour test:

Energy theoretically required to evaporate 5960 lb of water @ 245°F:

6,980,000 Btu/hr.

Energy actually expended in fuel (other energy inputs, i.e., electrical, are not considered):

11,750,000 Btu/hr.

Thermal efficiency:

$$\frac{6.98}{11.75} = 59.4.$$

Facility capacity

The above test is illustrative of the production capacity of this dryer unit, as the energy expended, 12,000,000 Btu/hr, approaches the nominal energy rating of 14,000,000 Btu/hr.

Raw product capacity:

8430 lb or 4.2 tons/hr @ 75% moisture.

Dry product capacity:

2470 lb or 1.2 tons/hr @ 75% moisture.

or, 4800 tons/yr, assuming plant operation of 16 hr/day,
250 days/year.

5.4 Considerations in Dryer System Evaluation

A definitive evaluation or comparison of dryer system options for potato waste dehydration has been impossible in this overview study; the following subjective comments are offered, however, to stress important considerations, advantages and disadvantages of the various dryer types. More detail concerning the direct-fired rotary and sonic drying systems is given because of the more in-depth coverage these two systems received during the study.

(a) Drying system complexity. It is apparent that, for dryer systems in which the feedstock receives substantial conditioning prior to drying (lime addition, dried product recycle), like the rotary and flash types, the unit processes are necessarily more numerous and the system operation more complex than for dryer systems which have no unique feedstock conditioning steps, like the sonic type. System complexity affects capital and operating costs.

(b) Air pollution potential. Regulation of air emissions, as well as other sources of industrial pollutants, is becoming increasingly more strict and, therefore, a dryer system which has low air pollution potential, such as the indirectly heated double drum and TorusDisc types, has a definite advantage over a dryer system with high air pollution potential, such as the sonic and rotary types. Air pollution abatement in the form of afterburner equipment to alleviate smoke and odour emission problems can be extremely costly; if system operation cannot be made to comply with smoke and odour emission standards without this equipment, then the economics of system operation are seriously degraded.

(c) Other environmental considerations. The consequences on system design of the noise associated with the operation of the sonic dryer must be fully appreciated in the evaluation of this system. The cost of adequate soundproofing to meet worker health and neighborhood noise criteria may be considerable.

(d) Maintenance. Two problem situations, one with the rotary and one with the sonic system, have come to light in the area of maintenance. With the direct-fired rotary dryer, fire in the drum caused by the ignition of material which has struck to the inner drum surfaces is a real hazard and, depending on the severity of the fire, may require replacement of the dryer drum. With the sonic system, maintenance and repair of structures and equipment may be brought about by the vibrational stresses associated with system operation. Neither of these problems can be quantitatively assessed with the data now available.

(e) Chemical addition. In those drying systems requiring chemical addition (lime) as a preconditioning step to drying, the cost of chemical may or may not be recovered in the sale of the dried product. This should be considered in any detailed economic analysis of system operation.

(f) End product quality. Samples of dried potato waste product from the Pillsbury rotary operation and the Roy, Washington sonic operation (trial run with pure dry caustic peel waste) can be physically characterized as a fairly coarse gritty material in the former case, and as a much finer gritty material in the latter. If fines are undesirable in the feed product, and there is research evidence to support that this is the case, then it is necessary to establish the extent to which the texture of the sonic dryer product can be controlled and whether this product meets quality criteria as a cattle feed ingredient.

If preservation of protein quality in the potato waste is ever considered an important feed criterion, then high-temperature short residence time dryers, such as the sonic and flash, appear to have better potential in meeting this goal than the moderate-temperature long residence time dryers, such as the direct-fired rotary. Low-temperature conduction dryers also have potential application when heat sensitivity is important.

(g) Dryer operational sensitivity. Of the two case illustrations, the sonic drying system appears to be the less sensitive to variability in feedstock characteristics, namely moisture content. In fact, system operation may be improved with high moisture feedstocks. This may be a

reflection of material handling aspects of the system, however, rather than on the drying process itself. The direct-fired rotary, on the other hand, has a more rigid operating range of feedstock characteristics which must be maintained in order that feedstock does not stick to the inner surfaces of the drum.

(h) Equipment versatility with other products. Both the direct-fired rotary and sonic dryers have proven performance with drying products other than potato waste. However, before this can be assessed as a possible advantage for a single drying installation, the compatibility of multiple product drying must be established by detailed system analysis.

(i) Past dryer experience. Further details, if available, on the reasons for the abandonment of a number of attempts at drying potato wastes with rotary type dryers would be invaluable in the assessment of this type of dryer system.

(j) Thermal efficiency. From the information available, the thermal efficiencies for the two dryer case illustrations are comparable. Future energy considerations may demand that higher thermal efficiencies, such as might be available with the superheated steam type of dryer, be obtained in order that the drying option be viable at all.

5.5 Summary

One type of dryer, the direct-fired rotary, is presently being used to dehydrate potato wastes. At present, there are only two such installations in North America, one in Maine and one in North Dakota. There have been other attempts in Canada and the U.S.A. to dry potato wastes using this type of dryer, but these have all been abandoned.

In preliminary selection of other drying systems that may have application for drying potato wastes, consideration must be given to the compatibility of the drying process and material to be dried, the effect the drying process has on the material in terms of feed quality, the air pollution potential of the drying process, the versatility of the dryer with other feedstock materials, and the cost of the dryer system.

One other type of drying system that shows good potential for drying potato wastes is the sonic dryer. An installation in the state of Washington is presently used to dehydrate wet poultry manure.

A subjective comparison between the rotary and sonic dryers indicates that, while the direct-fired rotary system is more complex and perhaps requires closer operating control than the sonic system, there is operating proof that this system is suitable for drying potato wastes. Further field work is required to substantiate the application of the sonic dryer to potato wastes.

Three other dryer types, the double drum, flash, and TorusDisc, may also have potential, but field trials would be necessary to substantiate this preliminary assessment.

6 POTENTIAL MARKET FOR A POTATO WASTE DRYING SYSTEM

6.1 Market Criteria Assessment

There are certain criteria that must be considered when examining the potential market for a system or product. The following are the important criteria that have influence on the marketing of a potato waste drying system.

(a) Pollution abatement regulations. The increased emphasis on environmental protection and the resulting federal, provincial and municipal regulations have placed pressure on industry to dispose of or utilize its waste products within acceptable environmental limitations.

Where the upgrading of plant waste treatment facilities or an alternate disposal method is required, the cost to industry for disposing of its waste products is generally greater than it was previously. In essence, the cost of pollution abatement today forms a higher percentage of total production costs than ever before. If this cost can be decreased by effective waste utilization, then not only industry but also the public could realize benefit.

(b) Alternate disposal methods. Potato processing waste solids in Canada are presently disposed of in wet form as cattle feed, in landfills, by lagooning, and by land spreading. If the present method is satisfactory, both economically and environmentally, for a particular plant, then there is little incentive for consideration of a drying system. If the present disposal method is not entirely satisfactory, then there is reason to consider alternative solutions, one of which is drying the wastes for animal feed. The drying option is given strength in those areas where the other methods are not practical, i.e., wet feeding cannot be considered in cold climates and in regions where the economics of commercial cattle feeding are poor¹ and land disposal cannot be carried out where physical constraints exist (topography, rainfall, etc.) in conjunction with pollution control regulations.

(c) Drying system economics. The overall economics of a potato waste drying system must be assessed in terms of the cost of drying and the revenue received for the dried product, as compared to the costs of

alternate disposal methods. The estimated costs and revenues for the direct-fired rotary system, which is presently used to dehydrate potato wastes, and the sonic drying system, which appears to have good potential for drying potato wastes (see Section 5), are shown in Tables 4 and 5. Schedules 1 and 2 justify the figures used.

The net cost of any investment cannot be accurately evaluated without considering income tax. Using the same cost and revenue figures, Tables 4A, 4B, 5A and 5B have been drawn up to include that tax. Tables 4A and 5A consider a 10 year straight line depreciation on fixed assets and Tables 4B and 5B incorporate ACCA (Accelerated Capital Cost Allowance). A firm is eligible for ACCA if pollution control equipment has been purchased before the end of 1976. Under ACCA, the capital cost of such equipment may be written off equally in the first two years, reducing taxable income and allowing for greater tax savings at that time.

The calculated net revenues for the dried products of the rotary and sonic systems were based on a drying facility being located at or near the potato processing plant site and, therefore, do not include the cost of transport of raw waste product that would occur if the drying plant were located some distance away. Cost figures were based on dryer manufacturer input, interpolation of data from the drying of other materials, and broad estimates. These figures are merely estimates and should not be used to make direct comparisons between the two drying systems, or as a basis for determining the absolute economic feasibility of drying potato wastes. However, they do show that drying of potato wastes could be economically feasible, and should be helpful to any plant considering this method of pollution control.

In a dryer feasibility study, consideration of future energy costs is important because fuel costs represent a large portion (over 50% in the examples given) of the total operating expenses of a drying installation. However, the cost of energy also affects the cost of conventional feedstuffs (production and transportation) and, therefore, the value of the dried product will reach a market level proportional to that of conventional feeds.

TABLE 4. ESTIMATED COST AND REVENUE, POTATO WASTE DRYING
SYSTEM - DIRECT-FIRED ROTARY DRYER

Capital Cost: \$270,000.00

- borrowed at 10% interest to be paid off in 10 equal annual
installments*.

Estimated Operating Expenses per hour*:

Fuel	\$26.95
Power (electric)	2.00
Labour	10.00
Maintenance	.75
Miscellaneous	<u>5.50</u>
TOTAL	\$45.20

- Estimated working hours are 16 hr/day,
250 days/year, 4000 hr/yr.

Operating Expenses per year: \$180,800.00

Estimated Revenue per ton: \$ 78.75*

- hourly output estimated at 1,700 pounds, @ 10% moisture content (.85
ton).

Revenue per hour: \$ 66.94

Revenue per year: \$267,750.00

Note: This dryer could dry the expected solid waste load from a plant
processing approximately 150,000,000 lb (75,000 tons) of potatoes
per year.

This dryer is capable of producing 3400 tons of dried potato per
year (4000 hr/yr @ .85 tons/yr).

*See Schedule 1 for details.

TABLE 4A
ESTIMATED NET CASH FLOW, POTATO WASTE DRYING SYSTEM - DIRECT FIRED ROTARY DRYER
- using 10 year straight line depreciation

ENTRIES	YEARS									
	1	2	3	4	5	6	7	8	9	10
<u>Profit-Loss Statement</u>										
Estimated Revenue	267,750	267,750	267,750	267,750	267,750	267,750	267,750	267,750	267,750	267,750
Tax Deductible Expenses: Operating Expenses	(180,800)	(180,800)	(180,800)	(180,800)	(180,800)	(180,800)	(180,800)	(180,800)	(180,800)	(180,800)
Depreciation (CCA)	(27,000)	(27,000)	(27,000)	(27,000)	(27,000)	(27,000)	(27,000)	(27,000)	(27,000)	(27,000)
Interest	(27,000)	(25,307)	(23,445)	(21,396)	(19,143)	(16,665)	(13,938)	(10,939)	(7,640)	(3,817)
Total Expenses	(234,800)	(233,107)	(231,245)	(229,196)	(226,943)	(224,465)	(221,738)	(218,739)	(215,440)	(211,617)
Profit-Loss before taxes	32,950	34,643	36,505	38,554	40,807	43,285	46,012	49,011	52,310	56,133
Tax (46% of profit-loss)	(15,157)	(15,936)	(16,792)	(17,735)	(18,771)	(19,911)	(21,166)	(22,545)	(24,063)	(25,821)
Net after Tax profit-loss	17,793	18,707	19,713	20,819	22,036	23,374	24,846	26,466	28,247	30,312
<u>Cash Flow Statement</u>										
Net after Tax profit-loss	17,793	18,707	19,713	20,819	22,036	23,374	24,846	26,446	28,247	30,312
Add: Non cash expenses (CCA)	27,000	27,000	27,000	27,000	27,000	27,000	27,000	27,000	27,000	27,000
Less: Principal Payments	(16,929)	(18,622)	(20,484)	(22,533)	(24,786)	(27,264)	(29,991)	(32,990)	(26,289)	(40,112)
Net Cash Flow	27,864	27,085	26,229	25,286	25,250	23,110	21,855	20,476	18,958	17,200

TABLE 4B
ESTIMATED NET CASH FLOW, POTATO WASTE DRYING SYSTEM - DIRECT FIRED ROTARY DRYER
- using Accelerated Capital Cost Allowance

ENTRIES	YEARS									
	1	2	3	4	5	6	7	8	9	10
<u>Profit-Loss Statement</u>										
Estimated Revenue	267,750	267,750	267,750	267,750	267,750	267,750	267,750	267,750	267,750	267,750
Tax Deductible Expenses: Operating Expenses	(180,800)	(180,800)	(180,800)	(180,800)	(180,800)	(180,800)	(180,800)	(180,800)	(180,800)	(180,800)
Depreciation (CCA)	(135,000)	(135,000)	-	-	-	-	-	-	-	-
Interest	(27,000)	(25,307)	(23,445)	(21,396)	(19,143)	(16,665)	(13,938)	(10,939)	(7,640)	(3,817)
Total Expenses	(342,800)	(341,107)	(204,245)	(202,196)	(199,943)	(197,465)	(194,738)	(191,739)	(188,440)	(184,811)
Profit-Loss before taxes	(75,050)	(73,357)	63,505	65,554	67,807	70,285	73,012	76,011	79,310	83,133
Tax (46% of profit-loss)	34,523	33,744	(29,212)	(30,155)	(31,191)	(32,331)	(33,586)	(34,965)	(36,483)	(38,241)
Net after Tax profit-loss	(40,527)	(39,613)	34,293	35,399	36,616	37,954	39,426	41,046	42,827	44,892
<u>Cash Flow Statement</u>										
Net after Tax profit-loss	(40,527)	(39,613)	34,293	35,399	36,616	37,954	39,426	41,046	42,827	44,892
Add: Non cash expenses (CCA)	135,000	135,000	-	-	-	-	-	-	-	-
Less: Principal Payments	(16,929)	(18,622)	(20,484)	(22,533)	(24,786)	(27,264)	(29,991)	(32,990)	(36,289)	(40,112)
Net Cash Flow	77,544	76,765	13,809	12,866	11,830	10,690	9,435	8,056	6,538	4,780

SCHEDULE 1. DETAILS ON COSTS AND REVENUES - DIRECT FIRED
ROTARY DRYER EXAMPLE

1) Capital Costs*

Dryer, Heil Model SD85-25	\$ 90,000
Accessory Equipment (product handling and storage)	60,000
Building	50,000
Installation, Erection & Freight	50,000
Miscellaneous (includes pollution control)	<u>20,000</u>
	\$270,000

Calculation of Annual Principal and Interest Payments

If \$270,000 is borrowed at a 10% interest rate, a firm is obliged to pay a fixed amount every year for 10 years. This amount (\$43,929**), includes all principal and interest payments for that time period. The table below shows the annual contributions to principal and interest. They vary because the interest paid is always 10% of the balance, and the total payment is the sum of the principal and interest payments. Interest is a tax deductible expense, and may be subtracted from total revenue each year before income tax is calculated. The principle payments are not tax deductible.

Year	Principal Balance	Principal Payment	Interest Payment	Total Payment
1	270,000	16,929	27,000	43,929**
2	253,071	18,622	25,307	43,929
3	234,449	20,484	23,445	43,929
4	213,965	22,533	21,396	43,929
5	191,433	24,786	19,143	43,929
6	166,647	27,264	16,665	43,929
7	129,382	29,991	13,938	43,929
8	109,392	32,990	10,939	43,929
9	76,402	36,289	7,640	43,929
10	40,113	40,112	3,817	43,929
Total	-	270,000	169,290	439,290

* This cost data supplied in part by The Heil Co.

** This annual payment is calculated from annuity tables, which provide a factor (.1627) to multiply with the capital cost (270,000) to give an annual payment (43,929) which includes both principal and interest (10%) payments for 10 years. (See Appendix.)

SCHEDULE 1. (CONT'D)

2) Operating Expenses

a) Fuel - based on information supplied by the manufacturer that, at an evaporation load of 6800 lb of water per hour, the dryer would have an estimated hourly energy demand of 11,186,000 Btu.

The following information sets out present fuel costs for various sources of energy by area in Canada.

Fuel Cost - \$/Million Btu's

Area	Energy Source			
	Nat. Gas	Bunker C	Diesel	Coal
British Columbia				
Lower Mainland	0.90	1.35	2.41	1.20
Interior	≤ 0.90	1.35	> 2.41	< 1.20
Prairies	0.25	1.67	2.41	1.20
Ontario	> 1.25	1.19	≤ 2.41	> 1.20
Maritimes	-	1.19	≤ 2.41	1.20

Source: B.C. Energy Commission

Using diesel fuel then, as the energy source for the Heil dryer, the estimated hourly fuel cost would be \$26.95 (11,186,000 Btu/hr @ \$2.41/million Btu).

b) Power - The system will require electrical power to operate the dryer drum and the material handling equipment. Estimated power costs as supplied by the dryer manufacturer are 100 kw per hour at \$.02 per kw.

c) Labour - Based on one full-time man (\$7.00 per hr) plus supervision (\$3.00 per hr) from an operating engineer. (This assumes that the dryer operation as part of the overall potato processing plant operation).

d) Maintenance - Based on an annual maintenance cost of \$3,000 (as estimated by the Heil Co.).

SCHEDULE 1. (CONT'D)

e) Miscellaneous - includes the cost of lime @ \$50 per ton, plus other miscellaneous operating costs.

Operating expenses are tax deductible.

3) Estimated Revenue

Revenue is based on 75% of the current selling price of barley per ton as set out in "Grain Facts", the publication of the Canadian Livestock Feed Board, on January 30, 1976:

$$75\% \times \$105.00 = \$78.75$$

At a production rate of 3400 tons per year annual revenue could be:

$$\$78.75 \times 3400 = \$267,750.00$$

4) Explanation of Tables 4A and 4B

a) Profit-Loss Statement. Profit, or taxable income, is total revenue minus expenses (operating expenses, depreciation, interest). If this is a positive amount, a tax rate of 46% is imposed on that income. If the amount is negative, there appears to be a loss, and providing the firm has alternative profits, this loss can reduce the overall tax burden. The saving is 46% of the recorded loss.

b) Cash Flow Statement. The net after tax profit is not the amount of cash that flows into the firm. A few adjustments must be made. Depreciation, which was treated as an expense in the profit-loss statement is a non-cash entry (the cash does not ever leave the firm); therefore, it must be added back. The principal payments were not involved in the profit-loss statement because they are not tax deductible. They must be deducted.

After these adjustments are made, it is clear how much money will actually flow into the firm.

TABLE 5. ESTIMATED COSTS AND REVENUES, POTATO WASTE DRYING SYSTEM - SONIC DRYER

Capital Cost: \$235,000.00*

- borrowed at 10% interest to be paid off in 10 equal annual installments*.

Estimated Operating Expenses per hour*:

Fuel	28.32
Power (electric)	2.00
Labour	10.00
Maintenance	.75
Miscellaneous	<u>1.50</u>
TOTAL	42.57

- estimated working hours are 18 hr/day, 250 days/yr, 4500 hr/yr.

Operating Expenses per year: \$191,565.00

Estimated Revenue per ton: \$ 84.00*

- hourly output estimated at 1,500 lb @ 10% moisture content (.75 ton).

Revenue per hour: \$ 63.00

Revenue per year: \$238,500.00

Note: This dryer could dry the expected solid waste load from a plant processing approximately 150,000,000 lb (75,000 tons) of potatoes per year.

This dryer is capable of producing 3375 tons of dried potato waste per year (4500 hr/yr @ .75 tons/hr).

*See Schedule 2 for details.

TABLE 5A
ESTIMATED NET CASH FLOW, POTATO WASTE DRYING SYSTEM - SONIC DRYER
- Using 10 year straight line depreciation

ENTRIES	YEAR									
	1	2	3	4	5	6	7	8	9	10
<u>Profit-Loss Statement</u>										
Estimated Revenue	283,500	283,500	283,500	283,500	283,500	283,500	283,500	283,500	283,500	283,500
Tax Deductible Expenses:	(191,565)	(191,565)	(191,565)	(191,565)	(191,565)	(191,565)	(191,565)	(191,565)	(191,565)	(191,565)
Operating Expenses	(23,500)	(23,500)	(23,500)	(23,500)	(23,500)	(23,500)	(23,500)	(23,500)	(23,500)	(23,500)
Depreciation (CCA)	(23,500)	(22,026)	(20,406)	(18,623)	(16,661)	(14,504)	(12,131)	(9,521)	(6,649)	(3,329)
Interest										
Total Expenses	(238,565)	(237,091)	(235,471)	(233,688)	(231,726)	(229,569)	(227,196)	(224,586)	(221,714)	(218,394)
Profit-Loss before taxes	44,935	46,409	48,029	49,812	51,774	53,931	56,304	58,914	61,786	65,106
Tax (46% of profit-loss)	(20,670)	(21,348)	(22,093)	(22,914)	(23,816)	(24,808)	(25,900)	(27,100)	(28,422)	(29,949)
Net after Tax profit-loss	24,265	25,061	25,939	26,898	27,958	29,123	30,404	31,814	33,364	35,157
<u>Cash Flow Statement</u>										
Net after Tax profit-loss	24,265	25,061	25,939	26,898	27,958	29,123	30,404	31,814	33,364	35,157
Add: Non cash expenses (CCA)	23,500	23,500	23,500	23,500	23,500	23,500	23,500	23,500	23,500	23,500
Less: Principal Payments	(14,735)	(16,209)	(17,829)	(19,612)	(21,574)	(23,731)	(26,104)	(28,714)	(31,586)	(34,906)
Net Cash Flow	33,030	32,352	31,607	30,786	29,884	28,892	27,800	26,600	25,278	23,751

TABLE 5B
ESTIMATED NET CASH FLOW, POTATO WASTE DRYING SYSTEM - SONIC DRYER
- using Accelerated Capital Cost Allowance

ENTRIES	YEARS									
	1	2	3	4	5	6	7	8	9	10
<u>Profit-Loss Statement</u>										
Estimated Revenue	283,500	283,500	283,500	283,500	283,500	283,500	283,500	283,500	283,500	283,500
Tax Deductible Expenses: Operating Expenses	(191,565)	(191,565)	(191,565)	(191,565)	(191,565)	(191,565)	(191,565)	(191,565)	(191,565)	(191,565)
Depreciation (CCA)	(117,500)	(117,500)	-	-	-	-	-	-	-	-
Interest	(23,500)	(22,026)	(20,406)	(18,623)	(16,661)	(14,504)	(12,131)	29,521	(6,649)	(3,329)
Total Expenses	(332,565)	(331,091)	(211,971)	(210,188)	(208,226)	(206,069)	(203,696)	(201,086)	(198,214)	(194,894)
Profit-Loss before taxes	(49,065)	(47,591)	71,529	73,312	75,274	77,431	79,804	82,414	85,286	88,606
Tax (46% of profit-loss)	22,570	21,892	(32,903)	(33,724)	(34,626)	(35,618)	(36,710)	(37,910)	(39,232)	(40,759)
Net after Tax profit-loss	(26,495)	(25,699)	38,626	39,588	40,648	41,813	43,094	44,504	46,054	47,847
<u>Cash Flow Statement</u>										
Net after Tax profit-loss	(26,495)	(25,699)	38,626	39,588	40,648	41,813	43,094	44,504	46,054	47,847
Add: Non cash expenses (CCA)	117,500	117,500	-	-	-	-	-	-	-	-
Less: Principal Payments	(14,735)	(16,209)	(17,829)	(19,612)	(21,574)	(23,731)	(26,104)	(28,714)	(31,586)	(34,906)
Net Cash Flow	76,270	75,592	20,797	19,976	19,074	18,082	16,990	15,790	14,468	12,941

SCHEDULE 2. DETAILS ON COSTS AND REVENUES - SONIC DRYER EXAMPLE

1) Capital Costs*

Dryer	\$ 75,000
Accessory Equipment	45,000
Building	50,000
Installation, Erection & Freight	45,000
Miscellaneous (includes pollution control)	<u>20,000</u>
	\$235,000

Calculation of Annual Principal and Interest Payments.

In this case the capital cost is \$235,000; therefore, the annual payments are \$38,235**. The principal and interest payments are as follows:

Year	Balance	Principal Payment	Interest Payment	Total Payment
1	235,000	14,735	23,500	38,235
2	220,265	16,209	22,026	38,235
3	204,057	17,829	20,406	38,235
4	186,227	19,612	18,623	38,235
5	166,615	21,574	16,661	38,235
6	145,041	23,731	14,504	38,235
7	121,310	26,104	12,131	38,235
8	95,207	28,714	9,521	38,235
9	66,492	31,586	6,649	38,235
10	34,906	34,906	3,329	38,235
TOTAL		235,000	147,350	382,350

* Manufacturer cost data was not available. These costs based on estimates.

** See Schedule 1 and Appendix.

SCHEDULE 2. (CONT'D)

2) Operating Expenses

a) Fuel - Based on information supplied by Sonic Drying Systems Limited that the dryer will have an estimated hourly energy demand of 11,750,000 Btu/hr. Using diesel fuel, then, the Sonic dryer will have a fuel cost of \$28.32 (11,750,000 Btu/hr @ \$2.41/million Btu).

b) Power - Assumed same as for rotary dryer example.

c) Labour - Assumed same as for rotary dryer.

d) Maintenance - Assumed same as for rotary dryer.

e) Miscellaneous - Incidental expenses; no lime costs.

3) Revenue

An adjustment in expected revenue has been made to reflect the fact that this product does not contain any lime (as does the rotary dried product) and, therefore, is of greater value. Revenue is based on 80% of the current selling price of barley:

$$80\% \times \$105 = \$84.00$$

At a production rate of 3375 tons per year, annual revenue would be: \$238,500.00.

4) Explanation of Tables 5A and 5B

See Schedule 1.

(d) Size of processing plant. The amount of potato waste available for drying will determine the size of drying system required. Figures were not available on the effect of size in relation to the economics of drying systems; however, as a general rule, larger drying plants would be considered more economic than smaller plants. In some cases, the economics of a drying system for potato wastes may be made more favourable by also drying other feedstuffs such as alfalfa, brewers' grains or other food processing by-products that are available in the area.

(e) History of potato waste drying systems. There have been a number of attempts to dry potato wastes that have been unsuccessful. These negative experiences will make it more difficult for a potato waste drying system to be marketed.

(f) Expertise. There is a lack of expertise within the corporate structure of the processing industry, both in regards to the physical aspects of the drying operation and the marketing of the dried potato waste. This may produce a reluctance to enter the field.

(g) Available capital. Dryer installations are capital intensive and would have to compete for funds against other capital projects within the company. If the company is capital short this can be a constraint, since the installation of a dryer system represents a new venture.

(h) Space. Lack of a suitable location for the dryer installation adjacent to or close by the potato processing plant, so that the drying operation can be brought into overall plant operation, could limit the marketing of a dryer system.

(i) Processor interest. Interest in the results of this study has recently been expressed by a number of potato processors in Canada and the United States, suggesting a seriousness on their part to consider the drying option.

6.2 Regional Market Assessment for Drying Systems

6.2.1 Canada

Figure 1, which appears in Section 2, provides a geographic distribution of potato processing plants in Canada. The following is an

overview of the market situation that exists for drying systems in the various geographic regions of Canada.

(a) British Columbia. The lower mainland region has seven small potato processing plants which presently dispose of their solid wastes by land disposal (landfill) and by feeding culls and similar waste products to cattle. It is not known whether these practices are satisfactory or if waste management upgrading is required. Constraints to consider in the evaluation of alternative disposal methods (including dehydration) for this region include: the mild winter climate is favourable to wet feeding of wastes to cattle; the economics of commercial cattle feeding are influenced by heavy rainfall in the area (necessitates covered feed storage and animal pens); individual processing plants are small; and, other products such as grass, and brewery and distillery by-products are available for drying.

One moderately sized potato processing plant is located at Creston in the southeastern interior of B.C. Constraints to consider for this region are: winter climate is cold, but not severe; economics of commercial cattle feeding may be adversely affected by lack of feeder animals and distance to market; land spreading for fertilizer is possible because the sodium content in the wastes is not high; and, alfalfa and brewers' waste grains are available for drying.

(b) Alberta. Alberta has six potato processing plants. The largest processes 100 million pounds of potatoes annually. Present disposal of waste solids is by landfill and feeding wet wastes to cattle. The winter climate makes wet feeding difficult during the colder months and this is the major constraint on this disposal method.

(c) Manitoba. One large and one small potato processing plant are located in Manitoba. Disposal of solid wastes is presently by landfill, land spreading, and cattle feeding. Winter conditions are a constraint on feeding wet wastes to cattle; a high sodium content in the waste material may have an adverse affect on soils where land spreading is carried out.

(d) Ontario. Most of the solid wastes from six potato processing plants in Ontario are being fed successfully in wet form to cattle.

(e) Quebec. There are twelve potato processing plants in Quebec, grouped primarily around Montreal and Quebec City. Present disposal of solid wastes is by landfill and for cattle feed. It is not known if present disposal practices are satisfactory or not. Small plant size could restrict individual dryer installations; two or three such installations, however, could have potential for serving all plants.

(f) New Brunswick. Two large and two small potato processing plants are located in New Brunswick. Present disposal of solid wastes is mainly by landfill and open pit dumping, and is not wholly satisfactory. Wet feeding of potato wastes appears unfavourable because of the relatively poor economics for commercial cattle feeding, and the problems associated with winter feeding. The drying option appears to have potential for the two large processing plants (150 and 250 million pounds raw potatoes processed annually); dried potato product could provide a source of energy feedstuff to the present local cattle industry.

(g) Nova Scotia and P.E.I. Three processing plants in Prince Edward Island and one in Nova Scotia presently dispose of solid wastes by landfill and cattle feed. The same constraints apply for disposal alternatives as for New Brunswick. The fruit processing industry in Nova Scotia may serve as a source of other by-products that could be dried.

6.2.2 United States

The following gives an overview of the market situations for a waste drying system that exist in the major potato processing regions of the United States.

(a) Washington and Oregon. Solid wastes are presently largely disposed of in wet form as cattle feed. Favourable economics for commercial cattle feeding and the mild winter climate make this an attractive method.

(b) Idaho & Malheur County Oregon. This is the largest potato growing and processing region in North America. The potato crop in Idaho alone is 70% greater than that for all of Canada. Wet solid wastes are presently disposed of primarily as cattle feed. Cold, but not severe,

winters provide some constraint on winter feeding of these wet wastes. J.R. Simplot, the largest potato processor in this region, has abandoned an attempt to dry potato wastes.

(c) North Dakota, Minnesota, Wisconsin, & Michigan. Cold winter temperature is a major constraint on feeding wet solid wastes to cattle. Dehydration of potato wastes is presently done by the Pillsbury Company in North Dakota.

(d) Maine. The somewhat poor economics of commercial cattle feeding, and unfavourable winter temperature, are major constraints on feeding potato wastes in wet form. Wastes are presently dehydrated at the Tater Meal plant in Presque Isle.

6.3 Summary

Among the various factors that affect the potential market for a potato waste drying system, perhaps the most important are: 1) whether there is a need for a particular processing plant, or regional group of plants, to consider an alternative to their present disposal practices, i.e., present practices may be environmentally unacceptable or economically unattractive; and 2) whether the drying option competes economically with other acceptable disposal alternatives for a particular processor.

Economics for the direct-fired rotary and sonic drying systems show a net return to the processor from the sale of dried potato wastes as livestock feed. However, these economics are general in scope and do not necessarily apply to any particular processing plant.

Based on the constraints on successful use of alternative disposal methods, there appears to be a potential market for a potato waste drying system in British Columbia, Alberta, Manitoba, Quebec, and the Maritime provinces. The biggest potential would appear to be in New Brunswick.

7 CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER WORK

7.1 Conclusions

(a) Dried potato waste marketability. Dried potato waste is an acceptable feed ingredient for ruminant animals (cattle, sheep), having an energy feed value comparable with that of barley. This product can be shipped, handled, stored, and reprocessed in much the same way as conventional dry feed (grains). Inclusion of this product in feed rations is particularly attractive for the grain deficient areas of eastern Canada.

(b) Dryer system evaluation. It is possible to dehydrate potato processing wastes using a system with a Heil direct-fired rotary dryer of triple-pass design. A newly developed dryer system, the sonic dryer, which is less complex and less sensitive to operate than the rotary system, also has good potential for this application, but further tests are required to verify operational compatibility with potato wastes. Other dryer types may also have potential, but since successful drying depends on compatibility between the material being dried and all components of the drying system, actual field tests are necessary to establish real system potential.

(c) Potential market for a drying system. The market potential for a drying system is better in those cases where the processor's present solid waste management program is not successful (i.e., environmentally unacceptable, costly) and in those cases where the drying option competes economically with other disposal alternatives.

The base economics of potato waste drying appear to be favourable with present technology. The whole question of dryer economics, however, must be considered in the context of pollution abatement benefits, and present and future energy constraints.

Small potato processing plants may be at a disadvantage because of the "economics of sale" and, therefore, may only be able to dehydrate their wastes in conjunction with other processing plants or with other products.

(d) Feeding wet potato wastes to cattle. Feeding wet potato wastes to feedlot cattle is a successful waste management alternative presently

being used in parts of Canada and the United States. This application is limited by the climate (more difficult in cold weather); the general economics of commercial cattle feeding in the area; the distance to the source of feed (processing plant); the specialized equipment necessary to handle wet potato wastes; and, size compatibility between an economic feedlot unit and the amount of waste available. Potato wastes form up to 70% of the total feed ration by weight.

(e) Overview assessment. In overview, an assessment of solid waste management for a potato processing plant, or any food processing plant with solid waste by-products, can only be made by examining the boundary conditions (climate, regional energy constraints, regional economics, pollution abatement regulations, etc.) that characterize the situation. The various combinations of boundary conditions found throughout North America dictate how a particular option for waste use or disposal is to be designed and what option is the most favourable for the given location or set of boundary conditions.

(f) Potato processing variation. There is variation in the character (texture, moisture content, chemical characteristics, etc.) of solid waste emanating from potato processing plants, depending on unit processes, specific equipment components, and waste recovery techniques within each plant. The drying option must be assessed in terms of the particular character of solid waste involved in each case because this will influence the selection of compatible system components including, in some cases, dryer type.

(g) Energy. In any high energy consumption process, such as the dehydration of a high moisture material, present and possible future energy constraints are of great importance in assessing the potential application of that process. Regional variation in energy costs and availability make it impossible to generalize on system applicability; careful consideration of these regional energy constraints is vital.

7.2 Recommendations for Further Work

On the basis of this study, further work is required in the following areas:

- (a) Detailed evaluations of commercial units drying potato waste are needed to generate system design and economic data. This work could be in the form of trial studies at existing commercial plants presently drying other material, or full scale studies at a commercially operating potato waste drying plant. This evaluation is required for both the sonic and rotary systems and, if possible, for other dryer types that have potential.
- (b) Detailed study of the conditioning of potato wastes prior to drying is required so that the methods of pH reduction and their effect on the drying system and on the feed value of the dried product can be evaluated.
- (c) More detailed study of the nutritional value of dried potato waste is required so that information on the economic value of this material in relation to other feedstuffs can be developed.
- (d) If a specific region in Canada establishes a greater use of potato wastes for inclusion in the rations of non-ruminant animals, then the option of cooking this material prior to wet feeding or drying must be further evaluated.

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APPENDIX

APPENDIX

Under the column "Capital Recovery Factor", this table supplies the factor by which a given P (present value) must be multiplied to give A (annual amounts) considering a 10% interest rate over any number of years, N , $(1 - \infty)$. In the case under consideration, $P = \$270,000$.

Discrete Compounding; $i = 10\%$

N	SINGLE PAYMENT		UNIFORM SERIES				N
	Compound Amount Factor	Present Worth Factor	Compound Amount Factor	Present Worth Factor	Sinking Fund Factor	Capital Recovery Factor	
	To find F Given P F/P	To find P Given F P/F	To find F Given A F/A	To find P Given A P/A	To find A Given F A/F	To find A Given P A/P	
1	1.1000	0.9091	1.0000	0.9091	1.0000	1.1000	1
2	1.2100	0.8264	2.1000	1.7355	0.4762	0.5762	2
3	1.3310	0.7513	3.3100	2.4869	0.3021	0.4021	3
4	1.4641	0.6830	4.6410	3.1699	0.2155	0.3155	4
5	1.6105	0.6209	6.1051	3.7908	0.1638	0.2638	5
6	1.7716	0.5645	7.7156	4.3553	0.1296	0.2296	6
7	1.9487	0.5132	9.4872	4.8684	0.1054	0.2054	7
8	2.1436	0.4665	11.4359	5.3349	0.0874	0.1874	8
9	2.3579	0.4241	13.5795	5.7590	0.0736	0.1736	9
10	2.5937	0.3855	15.9374	6.1446	0.0627	0.1627	10
11	2.8531	0.3505	18.5312	6.4951	0.0540	0.1540	11
12	3.1384	0.3186	21.3843	6.8137	0.0468	0.1468	12
13	3.4523	0.2897	24.5227	7.1034	0.0408	0.1408	13
14	3.7975	0.2633	27.9750	7.3667	0.0357	0.1357	14
15	4.1772	0.2394	31.7725	7.6061	0.0315	0.1315	15
16	4.5950	0.2176	35.9497	7.8237	0.0278	0.1278	16
17	5.0545	0.1978	40.5447	8.0216	0.0247	0.1247	17
18	5.5599	0.1799	45.5992	8.2014	0.0219	0.1219	18
19	6.1159	0.1635	51.1591	8.3649	0.0195	0.1195	19
20	6.7275	0.1486	57.2750	8.5136	0.0175	0.1175	20
21	7.4002	0.1351	64.0025	8.6487	0.0156	0.1156	21
22	8.1403	0.1228	71.4027	8.7715	0.0140	0.1140	22
23	8.9543	0.1117	79.5430	8.8832	0.0126	0.1126	23
24	9.8497	0.1015	88.4973	8.9847	0.0113	0.1113	24
25	10.8347	0.0923	98.3470	9.0770	0.0102	0.1102	25
26	11.9182	0.0839	109.182	9.1609	0.0092	0.1092	26
27	13.1100	0.0763	121.100	9.2372	0.0083	0.1083	27
28	14.4210	0.0693	134.210	9.3066	0.0075	0.1075	28
29	15.8631	0.0630	148.631	9.3696	0.0067	0.1067	29
30	17.4494	0.0573	164.494	9.4269	0.0061	0.1061	30
35	28.1024	0.0356	271.024	9.6442	0.0037	0.1037	35
40	45.2592	0.0221	442.592	9.7791	0.0023	0.1023	40
45	72.8904	0.0137	718.905	9.8628	0.0014	0.1014	45
50	117.391	0.0085	1163.91	9.9148	0.0009	0.1009	50
55	189.059	0.0053	1880.59	9.9471	0.0005	0.1005	55
60	304.481	0.0033	3034.81	9.9672	0.0003	0.1003	60
65	490.370	0.0020	4893.71	9.9796	0.0002	0.1002	65
70	789.746	0.0013	7887.47	9.9873	0.0001	0.1001	70
75	1271.89	0.0008	12708.9	9.9921	"	0.1001	75
80	2048.40	0.0005	20474.0	9.9951	"	0.1000	80
85	3298.97	0.0003	32979.7	9.9970	"	0.1000	85
90	5313.02	0.0002	53120.2	9.9981	"	0.1000	90
95	8556.67	0.0001	85556.7	9.9988	"	0.1000	95
100	13780.6	"	137796	9.9993	"	0.1000	100
∞				10.0000		0.1000	∞

" Less than 0.0001.

Source: E. Paul DeGarmo and John R. Canada, Engineering Economy, 5th edition, The MacMillan Company, New York, 1973.

